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PROCEEDINGS OF THE WORLD SYMPOSIUM ON WARM-WATER POND FISH CULTURE

ACTES DU SYMPOSIUM MONDIAL SUR LA PISCICULTURE EN ÉTANG A TEMPÉRATURE ÉLEVÉE

ACTAS DEL SIMPOSIO MUNDIAL SOBRE PISCICULTURA EN ESTANQUES DE AGUA TEMPLADA

Rome, 18-25 May 1966
Rome, 18-25 mai 1966
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Rome, Italy, 18-25 May 1966
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VOLUME IV - REVIEW, EXPERIENCE AND WORKING PAPERS OF MEETINGS IV, V AND VI

VOLUME IV - ETUDES SPECIALISEES, COMPTES RENDUS D'EXPERIENCES ET DOCUMENTS DE TRAVAIL DES REUNIONS IV, V ET VI

VOLUMEN IV - DOCUMENTOS DE INFORMACION, EXPERIENCIAS Y TRABAJO DE LAS REUNIONES IV, V Y VI

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Rome, January 1968 Rome, janvier 1968 Roma, enero 1968

PREPARATION OF THIS VOLUME

This is the fourth volume of the Proceedings of the FAO World Symposium on Warm-water Pond Fish Culture and contains the review, experience and working papers contributed to Meeting IV (on Breeding and Selection), Meeting V (on Biological and Other Methods of Increasing Production) and Meeting VI (on Standardization of Research Techniques).

The first volume contained the report of the Symposium; the second volume the regional and country reports, and the third volume the review and experience papers contributed to Meeting II (on Fertilization and Role of Soil in Fish Pond Productivity) and Meeting III (on Feeds and Feeding). The last volume of the Proceedings (Volume V) will contain the review and experience papers of Meetings VII to IX of the Symposium.

The views expressed in the contributions are those of the authors and not necessarily of the Food and Agriculture Organization of the United Nations.

Dr. (Mrs.) Rosemary McConnell and Dr. Homer Swingle assisted in the editing of some of the contributions.

PREPARATION DU PRESENT VOLUME

Le présent volume, le quatrième des Actes du Symposium mondial FAO sur la pisciculture en étang à température élevée, contient les études spécialisées, les comptes rendus d'expériences et les documents de travail présentés à la Réunion IV (Réproduction et sélection), à la Réunion V (Méthodes biologiques et autres d'accroissement de la production) et à la Réunion VI (Normalisation des techniques de recherche).

Le premier volume contient le rapport du Symposium; le deuxième les rapports régionaux et nationaux, le troisième les études spécialisées et les comptes rendus d'expériences présentés à la Réunion II (Fertilisation des étangs et rôle du sol dans la productivité) et à la Réunion III (Aliments pour poissons et alimentation artificielle). Le dernier volume des Actes du Symposium (volume V) contiendra les études spécialisées et les comptes rendus d'expériences présentés aux Réunions VII à IX.

Les opinions exprimées dans les communications sont celles des auteurs et ne représentent pas nécessairement celles de l'Organisation des Nations Unies pour l'alimentation et l'agriculture.

Mme. Rosemary McConnell et M. Homer Swingle ont collaboré à la mise au point de certaines des communications.

PREPARACION DE ESTE VOLUMEN

Este es el cuarto volumen de las Actas del Simposio Mundial de la FAO sobre Piscicultura en estanques de agua templada, y contiene los documentos de información, de experiencias y de trabajo que fueron presentados a la Reunión IV (sobre Cría y selección), Reunion V (sobre Métodos biológicos y de otro orden para aumentar la producción) y Reunión VI (sobre Normalización de las técnicas de investigación).

El primer volumen contiene el Informe del Simposio; el segundo, los informes regionales y nacionales, y el tercero los documentos de información y de experiencias presentados a la Reunión II (La fertilización y la función del suelo en la productividad de la estanicultura) y a la Reunión III (Tipos de alimentos y métodos de alimentación). El último volumen de las Actas (Volumen V) contendrá los documentos de información y de experiencias de las Reuniones VII a IX del Simposio.

Las opiniones expuestas en los documentos presentados son las de los autores de los mismos y no reflejan necesariamente las de la Organización de las Naciones Unidas para la Agricultura y la Alimentación.

La doctora Rosemary McConnell y el doctor Homer Swingle colaboraron en la redacción editorial de algunos de estos documentos.

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IV/R-1

FISH-HYBRIDIZATION

by

C.F. HICKLING
95 Greenway, London, U.K.

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Abstract

The object of hybridization of fishes is to develop improved qualities as compared with those of pure stocks, especially from the fish culture angle. Thus such hybrids sometimes show an enhanced rate of growth, greater hardiness, or a sex ratio skewed to 100 percent of one sex. In the last case, or where the hybrids are sterile, they are good material for planned pond stocking with assured control of the fish population.

Interspecific and intergeneric hybrids have been produced, especially among the Chinese and Indian major carps, and some of these appear to be fertile. But little has as yet been published on the qualities of such hybrids.

Caution is needed in hybridization work. Unless great care is taken, the presence of hybrid fish could endanger a normal fish breeding program. Further, hybrids may lose some especially valuable feature possessed by one of the parent stocks, and this has yet to be tested.

IV/R-1

L'HYBRIDATION DES POISSONS

Résumé

L'hybridation des poissons a pour objet de créer des sujets aux caractéristiques améliorées par rapport aux souches pures, notamment du point de vue piscicole. C'est ainsi que l'on peut obtenir des hybrides ayant un taux de croissance plus rapide, une rusticité plus grande ou avec un sex-ratio de 100 pour cent de mâles ou de femelles. Dans ce dernier cas, ou lorsque les hybrides sont stériles, ils se prêtent particulièrement à l'empoissonnement rationnel des étangs avec contrôle assuré de la population.

On a obtenu des hybrides inter-spécifiques et inter-génériques, notamment avec des carpes chinoises et les principales carpes indiennes et certains de ces hybrides paraissent fertiles. Toutefois, peu de renseignements ont été publiés jusqu'à présent sur les qualités de ces hybrides .

Le travail d'hybridation exige d'être mené avec beaucoup de précautions car, sans cela, la présence de poissons hybrides peut compromettre un programme normal de sélection piscicole. En outre, il peut arriver que les hybrides perdent une caractéristique particulièrement précieuse possédée par l'un des parents, mais c'est là un point qui demande encore à être vérifié.

HIBRIDACION DE LOS PECES

Extracto

El objeto de la hibridación es desarrollar mejores calidades en comparación con las de las formas puras especialmente por lo que se refiere a la piscicultura. Así pués, tales híbridos a veces muestran una mayor tasa de crecimiento, mayor resistencia, o a una proporción de sexos que se aproxima al ciento por ciento de uno sólo de éstos. En este último caso, o cuando los híbridos son esteriles, constituyen buen material para la repoblación planificada de los estanques mediante un control asegurado de la población íctica.

Se han producido híbridos interespecíficos e intergenéricos especialmente entre las carpas chinas y las carpas principales de la India, y algunos de ellos parecen ser fértiles. Pero, hasta el momento, poco se ha publicado sobre las cualidades de tales híbridos.

En los trabajos sobre hibridación es necesario proceder con prudencia. A menos que se adopten grandes precauciones, la presencia de peces híbridos puede poner en peligro un programa normal de cría de peces. Además, los híbridos pueden perder algunas de las características especialmente valiosas poseídas por alguno de los progenitores, extremo éste que tiene todavía que ser ensayado.

1 GENERAL

Hybrid fish are not rare in nature. Slastenenko (1957) lists 212 known hybrids belonging to 23 families, of which 91 are between cyprinids. Hubbs (1955) has shown that, in suitable conditions, the rate of natural hybridization may be high. For example, where two allied species of fish more or less share the same spawning ground, but where one of the species is more abundant than the other, hybridization may occur because individuals of the scarcer species have difficulty in finding mates of their own species. In such conditions, Hubbs found up to 90 percent hybrids among Lepomis in a Michigan stream. In fish culture, where a male and a female of different species can be isolated in a pond, breeding will often take place. So it is with several species of Tilapia; even intergeneric crosses may be made in such conditions, as with members of the sturgeon family Acipenser and Huso.

A brief review of fish hybridization up to the date of publication is to be found in a chapter of "Fish Culture" by Hickling (1962).

The development and improvement of induced spawning by hormone injection has widened the possibilities of fish hybridization, and the methods used will be the subject of other review papers.

2 INTRASPECIFIC HYBRIDS

A noteworthy recent case is the improvement of the common carp, Cyprinus carpio, by crossing cultivated common carp with wild carp from the River Amur. The common carp has been cultivated for many centuries in Europe, and European stocks have become very inbred (Schäperclaus, 1959). So, crossing with wild stock would be likely to give fish breeders a new start in the selective breeding of Cyprinus carpio. This cross is called the Kursk carp (U.S.S.R., 1964), and it is already known to have a greater resistance to cold temperatures than the cultivated carp. Hence the Kursk carp can carry fish culture into more northerly latitudes than the common carp.

The inheritance of the characters, scaliness (S) and nakedness (N) in the common carp has been well worked out (Kirpichnikov, 1945; Probst, 1949; Schäperclaus, 1959). Fully-scaled and mirror carp breed true, and both tend to have greater viability and a better rate of growth than the other two forms of common carp, namely, line-carp and leather carp. Probst suggests that, since the European customer prefers to buy carp with as few scales as possible, selective breeding should be done from mirror carp with the sparsest scale-cover, since even among scaled carp a reduced number of scales is hereditary.

3 INTERSPECIFIC HYBRIDS

3.1 Tilapia hybrids

3.1.1 Tilapia mossambica

The classification of the genus Tilapia is difficult, so it is not certain whether the cross made by Hickling (1960) between T.mossambica acclimatized for many years in Malaysia and Indonesia, and T.mossambica imported from Zanzibar, is intra- or interspecific. It is not known how T.mossambica reached Java about 1939. The T.mossambica of Zanzibar have been considered as a distinct subspecies of the T.mossambica species group,[1] so it may be convenient to consider these hybrids as interspecific.

Hickling showed that, when a male of the "African" strain is crossed with a female of the "Malayan" strain, the offspring are 98-100 percent males. Subsequent work, taking precautions, showed that 100 percent males are obtained in every case (Anon, 1963). The reverse cross, namely, the mating of a "Malayan" male with an "African" female gave male and female offspring in the Mendelian ratio of three males to one female. Some genetic factor is at work, and though theoretical explanations of the genetic mechanism have been made (Malacca, 1961) little confirmatory experimental work has yet been published.

---

[1] **This sub-species has since been distinguished from T. mossambica and named T. hornorum zanzibarica Trewavas - Ed.**

The hybrid males resulting from the cross "African" male by "Malayan" female grow faster than either parent stock (Hickling, 1959), and brood sizes are large. Conversely, the broods resulting from the cross "Malayan" male by "African" female are smaller in the number of individual offspring, and there may be a lethal factor present.

There are obvious advantages in breeding fast growing all-male Tilapia hybrids, for when stocked in suitably managed ponds they can give a crop of well-grown fish without the danger of overstocking through wild breeding. However, it is not always easy to do this. If one or more female fish find their way into the pond, broods of small fish will appear, for the hybrid males are fully fertile.

A disadvantage in the stocking of all-male hybrids is that the males are the nest builders. They hopefully make nests even in the absence of females, and the larger the fish, the larger the nest. The most favoured place for nest making is at the base of the pond dyke. The excavation of large bowl-shaped nests in such number that they may be continuous, during successive stockings, undermines the dyke to the point where it may collapse.

For this reason, something might be said for the breeding of all-female hybrids, which do not excavate nests. Their growth would be slower, and the yield probably be less. At Malacca, one "Malayan" male T.mossambica was found which gave 97 and 88 percent females when crossed respectively with two "Malayan" female T.mossambica, (Malacca, 1963). Unluckily, this male was lost, but a search for others might be worthwhile.

The all-male hybrids resulting from the cross "African" male by "Malayan" female have a breeding colouration resembling that of the "African" males; and the nests they build have the structure of those made by "African" males, which are distinct from those made by "Malayan" males (Hickling, 1960). The gillraker counts of the hybrids are intermediate between those of the parent stocks (Malacca, 1963).

Back-crosses between the hybrids and the parent stocks give offspring with a normal sex ratio of about 50 percent of each sex. In the breeding ponds, therefore, care has to be taken that none of the hybrid males grow to a size at which they could mate with the female parent, for the fry will then include some females. The precautions to be taken to avoid this have been described (Malacca, 1961; 1962).

3.1.2 T.mossambica X T.nilotica

Pruginin and Kanyike (1965) in Uganda, succeeded in crossing males of the Zanzibar strain of T.mossambica [1] with females of T. nilotica, in this case giving un undoubted interspecific hybrid. Again, the offspring of this cross was 100 percent male, and again, the hybrids showed a better rate of growth than either parent stock. These all-male hybrids give fish of a large size with good cropping rates, and they are stocked in the Uganda fish ponds in company with common carp. Pruginin and Kanyike reduce the risk of wild breeding from intruding female Tilapia by stocking a number of fingerlings of the predatory fish Lates niloticus in the ponds. These crop down any unwanted broods.

In their meristic characters, the T.mossambica males had a lower gillraker count (18-20) than those of the same stock imported to Malacca (21-23). The hybrids have a number of scales on the lateral lines intermediate between the parent fish; but the number of teeth in the upper and lower jaw was greater in the hybrids than in either parent stock. The number of gillrakers was the same as that of the female T.nilotica, and greater than that of T.mossambica.

No information is given on the colouration of the hybrid males, or of the structure of their nests.

---

[1] Now identified as T. hornorum zanzibarica Trewavas - Ed.

The fact that the males of the T.mossambica found in Zanzibar give 100 percent male offspring when crossed with the females of two distinct species of Tilapia suggests that these Zanzibar fish have something interesting in their genetic make-up. One would like to see these males crossed with females of other mouth-breeding Tilapia, such as T. macrochir, to see if this curious and important property applies more widely.

3.1.3 Other Tilapia crosses

Bard (1964) summarises the results of hybridization among other species of Tilapia. Crosses have been made as follows:-

In Katanga	T.andersonii X T.macrochir
In Zambia	T.andersonii X T.mossambica
In Cameroon and Ivory Coast	T.nilotica X T.macrochir
In East Africa	T.nigra X T.mossambica
In Rhodesia	T.mossambica X T.macrochir

The cross reported from East Africa of T.nigra X T.zillii has been doubted.

In Israel, Yashouv and Chervinsky (1959) reported a cross between T.galilaea and T. nilotica.

None of these hybrids were reported as showing skewed sex ratios or other more useful characters than the parent stocks.

3.2 Cyprinid hybrids

Chaudhuri (1959) produced, by hormone injection, followed by artificial fertilization, five interspecific crosses of Indian Labeo, as follows:-

Male L.rohita X female L.calbasu
calbasu X rohita
bata X rohita
bata X calbasu
calbasu X gonius

All these crosses gave viable young, and the growth rates of L. rohita X L. calbasu and L. calbasu X L. rohita were satisfactory. The majority of these interspecific hybrids were fertile (Chaudhuri, 1963). In a personal note, he kindly tells me that the rohita-calbasu gave a F2 generation in 1960. No detailed information is available on the rate of growth of these first and second generation hybrids as compared with the parent stocks.

3.3 Lepomis hybrids

In the U.S.A. interspecific hybrids have been produced among sunfishes. The object was to try to produce non-breeding fish to prevent over-population, and Lagler and Steinmetz (1957) found that 75 to 100 percent of the first generation hybrids of Lepomis gibbosus X L.macrochirus were males. The hybrids were not sterile, for young appeared; these may have been back-crosses with the parent female fish.

3.4 *Ictiobus hybrids*

Again, in the U.S.A.,Giudice (1964) produced interspecific hybrids of three species of buffalo fish, namely, *Ictiobus cyprinellus*, *I.bubalus*, and *I.niger*. In pond conditions, only *I.niger* X *I.cyprinellus* produced hybrid offspring; but by using hormone injections hybrids were produced as follows:-

female *I.niger* X male *I.cyprinellus*

niger X *bubalus*

bubalus X *cyprinellus*

While the offspring of the cross *bubalus* X *cyprinellus* grew at about the same rate as the parent stocks, those of the cross *niger* X *bubalus* grew about 10 percent faster in length than the parent stocks but weighed about the same. But the cross *niger* X *cyprinellus* grew 10 percent faster in length and 33 percent faster in weight than the parent species. The effect of this would be that it might be possible to grow market-sized hybrids of this cross in two years, instead of the three or more years required for the parent stocks, thus making their culture more feasible economically. No studies have as yet been published on the fertility and sex ratios of these hybrids.

In some 10 morphological characters examined, the hybrids were found to be intermediate between the parent stocks.

4 INTERGENERIC HYBRIDS

4.1 *Intergeneric hybrids of cyprinids*

A large number of intergeneric hybrids between members of the Cyprinidae have been produced; but, as might have been expected, many of them are not viable. What is more surprising is that some of them are not only viable, but fertile, and one has produced an F2 generation.

4.1.1 Indian Major Carps

Chaudhuri (1959) made the following successful intergeneric crosses:-

Male		Female
Catla catla	X	*Labeo rohita*
Catla catla		*Labeo calbasu*
Catla catla		*Cirrhina mrigala*
Labeo rohita		*Cirrhina mrigala*
Cirrhina mrigala		*Labeo rohita*
Cirrhina mrigala		*Labeo calbasu*
Cirrhina reba		*Labeo rohita*
Cirrhina reba		*Labeo calbasu*

The *catla-rohita* hybrid had one feature of value, namely, a broad body like that of *catla*, but a small head like that of *rohita*. Where consumers do not eat the head of a fish such a hybrid would have a selling advantage over the parent stocks. Chaudhuri (personal note) tells that the *catla-rohita* hybrids are not only fertile, but produced an F2 generation, which had a satisfactory growth rate.

4.1.2 Hybrids between Indian and Chinese major carps

Alikunhi, Sukumaran and Parameswaran (1962) attempted to produce a large variety of intergeneric hybrids of Indian and Chinese major carps, with the following results:-

Embryos died before hatching:	*Catla catla* X *Aristichthys nobilis*
	Labeo rohita X *A.nobilis*
Hatchlings died on the first day:	*Hypophthalmichthys molitrix* X *Catla catla*
	Catla catla X *Ctenopharyngodon idella*
	L.rohita X *C.idella*
	C.catla X *H.molitrix*
Hatchlings mostly died within a week :	*C.idella* X *L.rohita*
	H.molitrix X *L.rohita*

It is interesting to note that one of the hybrid offspring of *C.idella* and *L.rohita* survived for two weeks.

Chaudhuri (personal note) in 1963 crossed *C. idella* male with *Cirrhina mrigala* female and found that 95 percent of the eggs hatched. But their growth was abnormal, and all died within a few days. While the writer was at Cuttack in August 1965, Dr. Chaudhuri again tried this cross, but with the same result.

4.1.3 Chinese major carps

Tang (1964) reports the successful crossing of the *H.molitrix* with *A.nobilis*. Thousands of fingerlings of this cross were growing well in his ponds. The writer saw many batches of this intergeneric hybrid growing in Taiwan during his visit in May, 1965. Nothing has yet been published on the rate of growth and other properties of this hybrid.

Alikunhi, Sukumaran and Parameswaran (1962) crossed *C.idella* with *A.nobilis*, and *H. molitrix* with *A.nobilis*, but the embryos died before hatching.

Nikolsky (personal note) records the following intergeneric crosses made in Russia:-

Female		Male
H.molitrix	X	*A.nobilis*
A.nobilis	X	*H.molitrix*
H.molitrix	X	*Megalobrama terminalis*
H.molitrix	X	*Parabramis pekinensis*

C.idella X Parabramis pekinensis

C.idella X H.molitrix

C.idella X A.nobilis

C.idella X Megalobrama terminalis

Detailed results of these investigations will be published in the near future.

From the above results it seems that it is less difficult to produce viable offspring from intergeneric crosses among Indian major carps, and among Chinese major carps, than between Indian and Chinese major carps.

4.1.4 Intergeneric crosses of Cyprinus carpio

Nikolsky (Personal note) records the successful crossing of C.carpio males with H. molitrix females, and of C.carpio male with C.idella female, and C.idella male with C. carpio female. The results will be published in the near future.

Tang (1964) reports the success of Lin in crossing Cirrhina molitorella males with females of C.carpio, with the production of a considerable number of fingerlings. Some of these grew to a weight of 1.35 kg (range from 1.2 to 1.5 kg) during a period of one year in an ordinary fish pond. No comparison, however, is given with the rate of growth of the parent stocks in the same environmental conditions.

Alikunhi and Chaudhuri (1959) obtained crosses of male C.carpio and female Labeo rohita. The growth of these hybrids was reported to be satisfactory, but they proved to be sterile.

In Germany, Lieder (1957), using pituitary injections, obtained crosses between C. carpio and Carassius auratus. The hybrids were almost completely sterile, so they appear to be suitable fish for stocking as there would be little or no wild spawning, and so no danger of the over-population of the pond. As in the parent stock of C. carpio, the hybrid offspring included both fully-scaled and partly-scaled fish. These hybrids were notably disease-resistant, grew only slightly less fast than C. carpio, and resembled C. carpio sufficiently to fetch the same market price.

Lieder quotes the work of Nikoliunin with carp-Carassius hybrids. This worker did a back-cross of the female carp-Carassius hybrid with male C.carpio. These back-crossed hybrids grew slightly better than C.carpio, when grown in the same pond, and suffered less mortality. Their sex-ratio was considerably skewed to about 80 percent males.

4.2 Intergeneric hybrids of sturgeons

Nikoliunin and Shpilevskaia (1959) reported on hybrids of the sterlet (Acipenser) and the beluga (Huso). These two genera may produce hybrids spontaneously in ponds, and the hybrids are viable. The male hybrids from the cross Huso female by Acipenser male produce ripe sperm, and these were crossed back with pure line Huso females. The offspring had the faster growth rate of Huso combined with the ability of Acipenser to remain in fresh water.

The females of the cross are sterile, and they are therefore useful for stocking enclosed waters.

5 DISCUSSION

5.1 Purpose of hybridization of fishes

The motives behind hybridization in fishes is a search for improved qualities. Since many interspecific crosses among higher animals are known to be sterile "mules", interspecific and intergeneric hybrids among fishes might prove sterile. In view of the great fecundity of fish, and the problems posed by the "wild breeding" of fish under cultivation, sterile fish would be valuable. With such fish, planned crops would become generally feasible. Further, sterile fish might have a faster rate of growth or produce a fatter fish (where this is a desirable character). They might have other useful qualities, such as a non-migratory habit. But in fact, many fish hybrids, both interspecific and even intergeneric, are not sterile. Sometimes, but not always, they have a faster rate of growth than the parent stocks, and they may have an improved shape.

A very much skewed sex ratio sometimes results from hybridization, and in cases where hybridization gives 100 percent of one sex, the hybrids are hypothetically as useful as sterile fish for stocking with the added advantage of population control.

Caution is needed in this hybridization work. For example, it is possible to breed out good qualities as well as to produce them. This may especially be so where a fish has some specialized quality which makes it valuable. Examples are fish such as the white Amur, or grass carp, Ctenopharyngodon idella, and the Tolstobik, or Silver carp, Hypophthalmichthys molitrix. The former has a pharyngeal dentition specialized for the rasping and grinding of fresh plant material; while the latter has a filtering apparatus on the gill-arches (Verigin, 1957) which enables it to strain off and feed on very small particles, such as phytoplankton, and including, it is suspected (Stroganov, 1963) blue-green algae. If hybrids of these fish with other cyprinids are without these peculiarly useful characters, the hybrids will be less, not more, useful than the parent.

Further, too many hybridization experiments could endanger a fish breeding program, inasmuch as it might not always be possible to be sure that individual fish used as breeders are in fact from a pure strain of the species which it is desired to breed.

5.2 Difficulties in hybridization work

The large-scale breeding of hybrid fish is in practice limited by the number of ponds available. Most fish breeding stations have pond space enough only for the breeding of known useful species (and it is the general experience that they could do with much more).

Further, as Schäperclaus (1959) has pointed out, to follow a cross to the F2 and F3 generations would involve the rearing of very large numbers of fish to maturity. If such fish have to be divided among many ponds, qualities due to heredity may be masked by differences due to varying fertility of the ponds. The effect of environment may be greater than that of heredity where fish have to be divided among many ponds, thus stultifying comparisons which might point to improved qualities in the hybrid fish.

Fish hybridization work is very recent; and it seems that where it is being done, some, at least, of the hybrids should be reared to a size at which their properties, such as colour, meristic characters, sex ratio, gonad development, and rate of growth in comparison with, and under the same environmental conditions as the parent strains can be defined. As yet we have little such information. Work can then be concentrated on those hybrids, whether interspecific or intergeneric, which show characters desirable in fish culture and superior to those of the parent strains, and the rest can be rejected. It is much to be hoped that at this Symposium more up-to-date and complete information on the properties of fish hybrids will be brought forward.

It would seem that the sole justification for setting aside pond space for the growing of hybrids is the practical one of producing fish with qualities superior to those of the pure strain now being bred, or which may be bred in the future.

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IV/R-2

GENETIC IMPROVEMENT OF YIELD IN CARP

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IV/R-2

GENETIC IMPROVEMENT OF YIELD IN CARP

Abstract

Eight years of investigation of the genetics of growth rate in the carp (Cyprinus carpio) yielded the following major results:

(i) There was no detectable response to mass selection for faster growth rate, while selection for slower growth rate resulted in a response expected when heretability is 0.20-0.30.

(ii) Large differences were found in growth rate and yield capacity between means of full-sib families.

(iii) A single generation of brother-sister mating usually resulted in strong inbreeding depression of growth rate and viability.

(iv) Inter-family cross-breds, showed, on the other hand, a high degree of heterosis over their inbred parents.

(v) A correlation of 0.3-0.5 was found between relative growth rate in communal ponds and yield capacity in mono-progeny ponds.

The above results led to the conclusion that genetic differences, perhaps of non-additive nature, form the major determinant of variation between family means. On the other hand non-hereditary components, in particular interactions between fish, determine most of the variability within a spawn.

In view of the strong inbreeding depression, heterosis and lack of response to mass selection for faster growth rate, it is indicated that the basic feature of any effective breeding program in carp should be the production of selected cross-bred commercial fingerlings.

The method of screening for cross-bred combinations employed by the Israeli Breeders Union is outlined. Similarly, a procedure is described, for reciprocal recurrent selection in carp, supplemented by 'open gene pools' and the use of mutants for body colouration as genetic markers.

AMELIORATION GENETIQUE DU RENDEMENT DE LA CARPE

Résumé

Huit années de recherche sur les caractéristiques génétiques du taux de croissance de la carpe (Cyprinus carpio) ont donné les principaux résultats suivants:

(i) La sélection massale pour un taux de croissance plus rapide n'a donné aucun résultat décelable, tandis que la sélection pour un taux de croissance plus lent a donné la réaction escomptée lorsque l'héritabilité se situait entre 0,20 et 0,30.

(ii) On a constaté de grosses différences dans les moyennes de taux de croissance et de capacité productive entre des familles de frères et soeurs pleins.

(iii) L'accouplement entre frère et soeur entraîne généralement, au bout d'une seule génération, une dégénérescence consanguine marquée qui influe sur le taux de croissance et la viabilité.

(iv) Les produits de croisement entre familles accusent, par contre, un degré élevé d'hétérosis par rapport à leurs parents consanguins.

(v) Une corrélation de 0,3-0,5 a été notée entre le taux de croissance relatif dans les étangs communs et la capacité de production dans les étangs à mono-progéniture.

Ces résultats amènent à conclure que ce sont des différences génétiques, peut-être de caractère non additionnel, qui forment le principal élément déterminant la variation entre moyennes familiales. En revanche, ce sont des éléments non héréditaires, notamment les actions réciproques entre poissons, qui déterminent pour l'essentiel la variabilité à l'intérieur d'une famille issue de la même ponte.

Etant donné l'importance de la dégénérescence consanguine, de l'hétérosis et le manque de réactions à la sélection massale pour un taux de croissance plus rapide, il semble qu'en carpiculture tout programme de sélection efficace devrait avoir pour objet essentiel la production, par croisement de première génération, de fingerlings sélectionnés à des fins commerciales.

La communication donne des indications sur la méthode employée par l'Union des sélectionneurs israéliens pour recherche de nouvelles combinaisons de croisement. On trouvera de même la description d'une procédure applicable à la sélection récurrente réciproque chez la carpe, complétée par des systèmes "de réservoirs de gènes ouverts" et l'emploi de mutants pour la coloration du corps en tant que marque génétique.

MEJORAMIENTO GENETICO DEL RENDIMIENTO DE LA CARPA

Extracto

Ocho años de investigaciones sobre la genética del ritmo de crecimiento de la carpa (Cyprinus carpio) proporcionan los siguientes resultados principales:

(i) No se registró ninguna respuesta sensible a la selección masal para un mayor ritmo de crecimiento, en tanto que la selección para la disminución del ritmo de crecimiento determinó una respuesta esperada cuando la herencia es de 0,20-0,30.

(ii) Se observaron grandes diferencias en la tasa de crecimiento y en la capacidad de rendimiento entre las medias correspondientes a familias obtenidas por cruzamiento entre hermanos.

(iii) Una única generación de acoplamiento hermano-hermana determinó como resultado una gran depresión por consanguinidad del ritmo de crecimiento y de la viabilidad.

(iv) Los cruzamientos entre familias mostraron, por otra parte, un alto grado de heterosis respecto a sus progenitores cruzados.

(v) Se halló una correlación de 0,4-0,5 entre el ritmo de crecimiento relativo en los estanques comunales y la capacidad de rendimiento en los estanques con progenie única.

Los resultados anteriores condujeron a la conclusión de que las diferencias genéticas, quizás de carácter no acumulativo, forman la principal determinante de la variación entre las medias familiares. Por otra parte, las componentes no hereditarias, en particular la interacción entre peces, determinan la mayor parte de la variabilidad dentro de una freza.

En vista de la gran depresión determinada por la consanguinidad, la heterosis y la falta de respuesta a la selección masal para un mayor ritmo de crecimiento, se señala que la característica básica de cualquier programa de cría selectiva de carpas debería ser la producción de alevines seleccionados y obtenidos por cruzamiento en forma comercial.

Se describe a grandes rasgos el método de selección para la combinación de cruzamiento empleado por la Unión de Criadores Israelíes. Análogamente, se expone un procedimiento para la selección recurrente recíproca de la carpa complementado por "agrupaciones de genes abiertos" y el empleo de mutantes para la coloración del cuerpo como trazadores genéticos.

1 INTRODUCTION

Eight years ago we initiated a program of genetic studies aimed at improving growth and yield of carp (Cyprinus carpio). A search of the literature and discussions with carp breeders revealed that little information was available on the basic genetic parameters needed for the evaluation of breeding programs in carp. Therefore, as an integral part of our breeding program we conducted studies on these basic questions.

To carry out the breeding program on a commercial basis, the Israeli Fish Breeders Union has been organized. It comprises five settlements, one in each of the five fish-growing regions of Israel. The member settlements work in cooperation on a single breeding plan, under the supervision of our genetic team.

Two types of information are needed for the design of efficient breeding programs for any particular trait. First, the relative importance of hereditary and environmental factors in determining the phenotypic variation of the trait. This parameter is known as the heritability of the trait. If heritability is high then the phenotypic value of an individual will be a good indication of his genetic value, and mass selection may be effective. If heritability is low then more complex methods of selection, family selection or progeny testing, must be used in order to identify genetically superior individuals. The second type of information required is the relative importance of additive and non-additive genetic factors affecting the trait. If additive genetic factors are important, then selection within a population (whether by mass selection or family selection) will be effective in improving the trait. If non-additive genetic factors are important, then some sort of cross-breeding scheme will be necessary in order to achieve maximum progress. Although growth rate has generally been found to be determined primarily by additive genetic factors, it will be seen that the situation is probably different in carp.

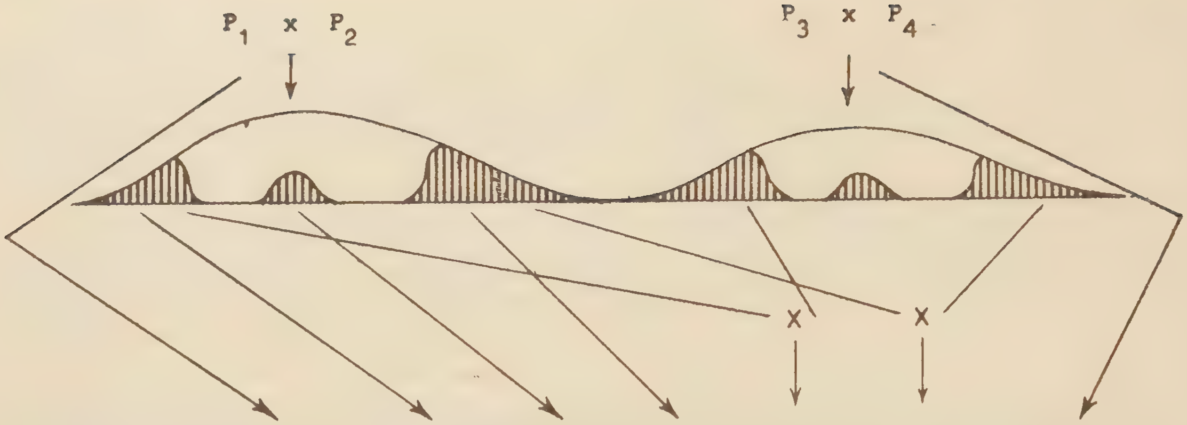
This paper deals with the major findings of our investigations, and outlines procedures for their use in the genetic improvement of carp.

2 RESULTS OF EXPERIMENTS

2.1 Individual selection

One of the simplest, yet most effective method of estimating heritability is to carry out a two-way selection experiment, i.e. to raise offspring out of the best and poorest individuals in the population. If the offspring of the up and down selected parents are found to differ considerably, in the expected direction, then additive genetic factors are an important source of variation of the trait in question. The precise degrees of importance will depend on the degree of the response relative to the selection intensity imposed, i.e., to the difference between offspring groups divided by the difference between their respective parental groups. This ratio may be termed the effective heritability of the trait. If the offspring of the up and down selected parental groups are not found to be different, then it can be concluded that additive genetic factors are of little relative importance.

We carried out over a dozen one-step selection experiments, aimed at finding the response to mass selection. Five typical results are presented in Fig. 1, rows 1 and 2 show the difference between the progeny of individuals selected for large weight (henceforth 'jumpers', and individuals at the mean of the population (henceforth 'medians'). In both cases the progeny of the 'medians' had a faster growth rate (not significantly so) than the progeny of the 'jumpers'. An equivalent comparison carried out on progeny of cross-bred fish is presented in row 5. Here 'jumper' males of one group were mated with 'jumper' females of a second group, the mean gained weight of their progeny was 624 g per fish. The unselected control in this case is the mean of the two repeated F1 progenies[(578+672)/2=625]. Here again the upwards selected group showed no response. The downward selected group, on the other hand, showed a noticeable response. The average difference between the progeny of the 'jumpers' and the progeny of the group selected for small body weight (henceforth 'laggards'), of the four comparisons in Fig. 1 was 33 g.


P_1 x P_2
P_3 x P_4
X
X

Year	F_1 repeat	Inbreeding (F_2)			Crossbreeding		F_1 repeat
		down	centre	up	down	up	
1961	447	-	385	363	-	-	-
1964	-	547	621	591	-	-	-
1962	669	587	-	591	-	-	-
1964	-	602	-	655	-	-	-
1962	578	-	-	-	593	624	672

Fig. 1 Results of selection and inbreeding experiments in carp. (Values in the table are averages of gained weights, per fish in grams, corrected for initial weights).

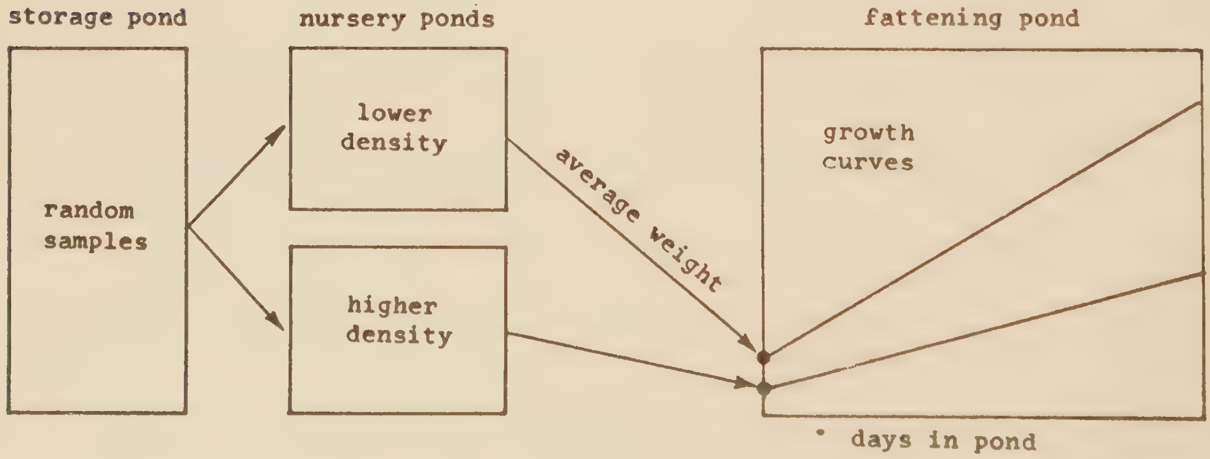

storage pond
nursery ponds
fattening pond
random samples
lower density
higher density
average weight
growth curves
days in pond

Fig. 2 The multiple-nursing method for formation of random samples with varying average weights from a single progeny

The difference between the means of the selected 'jumpers' and 'laggard' parents themselves were between 200 to 300 g. Thus, the regression of offspring on parents, or the realized heritability, based on the difference between the 'jumpers' and 'laggards' was 0.10 to 0.15. If, however, we divide the selection differential into two parts; 'laggards' to 'medians', and 'medians' to 'jumpers', we find a realized heritability of 0.2 to 0.3 for downward selection, and a heritability of zero for upward selection.

This asymmetry of response is characteristic of plateaued selected populations, i.e., populations that, as a result of long continued selection, either natural or artificial, have exhausted their additive genetic variability, and no longer respond to selection. Such populations have also been found to have a zero heritability in the up direction, but medium heritabilities in the down direction. In these cases considerable amounts of non-additive genetic variation have been shown to remain in the populations.

2.2 Progeny tests

When the cause of a low heritability is a large environmental variation, the classical animal breeding solution is to make use of family-selection or progeny testing. That is, judging the genetic worth of a family by the means of a large number (say 30-80) individuals in that family, or alternatively judging the genetic worth of an individual, or a particular parental pair, by the means of a large number of their offspring. If well designed, such selection schemes will greatly reduce environmental sources of variation and enable families, individuals, or parental pairs, with superior genetic merit to be selected. Accordingly, a progeny testing scheme was instituted seven years ago, and since then we have conducted large-scale progeny tests annually. The statistical analysis of these tests yielded estimates of the total genetic variance in the Israeli carp population. Most of the progeny tests were conducted in the settlements that now constitute the Israeli Fish Breeders Union.

The method followed for these tests was as follows: all progenies that were to be tested in one year were spawned within a single week, each spawn in a separate pond. The progeny of each spawn were nursed in separate ponds to an average weight of about 30 g. At this point, (5 to 6 weeks after spawning) random samples of each group were brand-marked, and in a single day all groups were stocked in several commercial fattening ponds at densities of 200 to 250 fish per dunam (1,000 m^2).

The fattening ponds, each of which constituted a replication of the same progeny test, were each located in a different settlement. For illustration, Table I shows the results of the tests conducted in 1964 (Wohlfarth, 1965). Sixteen progenies were tested in five replications. The first six were the offspring of a single pair of parents and are therefore full-sib groups. The progenies 7 to 11 and 14 were each the offspring of mass-matings between a single female on the one side and several brothers, unrelated to her, on the other. The remaining four progenies were the offsprings of mass-matings between several sisters, on the one side, and several brothers, unrelated to them, on the other.

All the above progenies, may be treated as the equivalents of full-sib families. With one possible exception (progeny 6) there was no immediate or known family relationship between the male and the female parents of the same spawn. In progeny 6, there is a fairly high probability that a first-degree relationship existed between the male and female parents, hence the poor performance of this group can be attributed to inbreeding depression.

In the last three spawns, one side consisted of several individuals belonging to an inbred group imported from Holland. The remaining 13 progenies may be treated, with some reservation, as a random sample of the Israeli carp population. An analysis of variance (Table Ib) shows that the difference between the progeny means are highly significant, and the estimate of the 'between-progeny means' variance is 2,077 GR^2. Similar tests were conducted in previous years and have been analyzed in the same fashion. Pooling the information accumulated over several years, the total genetic variance between means of full-sib families in the Israeli carp population was estimated to be about 1,500 GR^2.

Table I

Progeny tests of carp, conducted by the Israeli Fish
Breeders Union in 1964

a) Corrected average weights gained per fish in grams, in fattening ponds of five settlements

Settlement	Progeny 1	2	3	4	5	Mean
1	728	586	521	563	455	571
2	706	548	502	546	408	542
3	717	-	510	526	390	543 1/
4	697	576	479	-	378	528 1/
5	-	496	450	461	345	480 1/
6	566	493	395	429	318	440
7	910	666	553	583	403	623
8	739	-	518	523	473	571 1/
9	706	585	536	568	412	561
10	695	527	497	483	375	515
11	582	598	461	511	367	504
12	780	613	561	576	422	590
13	729	560	547	525	410	554
14	783	633	541	5866	424	593
15	780	623	556	589	401	590
16	-	544	470	510	400	523 1/

1/ For computation of the mean, when an observation was missing the 'missing-plot' technique was used.

b) Analysis of variance table of the first 13 progenies of the above table (See text for details).

Source of variation	Degree of freedom	Mean square
Between progeny	12	11510
Between ponds	4	166999
Interaction	44	1125

$$0^{2}_{\text{prog}} = \frac{MS_{\text{prog}} - MS_{\text{int}}}{5} = 2077$$

The genetic variance between full-sib groups includes one-half of the additive variance, plus one-fourth of the dominance variance, plus a smaller fraction of the sum of the 'interactions' variance. It is therefore reasonable to assume that the total genetic variance within progenies is just as high, or higher, than the estimated 'between progeny' variance. The total genetic variance of the population can therefore be estimated to be in the range 2,000-4,000 GR^2. It should be noted that this figure relates only to gained weights under the following conditions: growing season - summer and autumn growing period - from 30 g to about 600 g, and density of stocking 200-250 fish per dunam.

Analysis of the progeny-tests results also provides estimates of the following variance components: progeny x pond interactions, progeny x year interaction, 'common environment' effects, and the 'error variance'. All were found to be in the range of 200 to 600 GR^2 and were thus quite small relative to the total genetic variance component. When progeny tests are replicated in as few as four ponds, it can be shown that about 70 percent of the differences between progeny means can be attributed to genetic variation. Hence, ranking progenies according to their performance in the progeny tests is highly correlated with their genotypic values, and progeny tests provide an effective tool for identifying genetically superior progenies and parental groups.

2.3 The effect of differences in initial weight on weight gain in communal ponds

In making use of progeny testing, care should be taken to account for the influence of the initial weight of a progeny group on its average weight gain. Differences in the initial weights of the tested progenies arise in the following manner. The progeny testing in communal ponds commenced after each progeny had been reared in a separate nursery pond. The nursery ponds were of different fertilities and fish densities, therefore weight gains in the different ponds could not be completely controlled, hence the average weights of the different progenies were not identical when the fattening ponds were stocked. It was found that progenies with larger initial weights (due to the purely environmental reasons mentioned above) tended to show larger weight gains than progenies with lower initial weights, i.e. relative growth rate in the communal ponds was positively correlated with initial weight. Thus initial weight differences exerted a distorting influence on the results of progeny tests (Wohlfarth *et al.*, 1965).

In 1962 and 1963 a series of experiments aimed at determining the regression of weight gains on initial weights was conducted. The basic features of the method used for this purpose (termed the 'multiple nursing' technique) were as follows (Fig. 2): from a fingerlings storage pond containing full-sibs, two or more random samples were drawn and introduced into separate nursery ponds at various stocking densities. Since growth rate is strongly influenced by stocking density, the fingerlings in the less densely stocked ponds grew faster than their sibs in the more densely stocked ponds. When the average weights of the fingerlings in the nursery ponds reached the desired values, the different groups of fish were brand-marked and stocked together in a single fattening pond. This technique created an initial weight difference of purely environmental origin, hence the regression of average weight gains on initial weights can be used to derive a 'correction term' to be used in correcting gained weights for differences in initial weights of different progenies.

Under the specific conditions of our tests a one g difference in initial weight was found to result in a three to four g difference in weight gain. Thus, a correction of gained weight to a standard initial weight, presumably makes the between-progeny differences independent of differences in initial weights, and it increases considerably the accuracy of the ranking of the genotypic values of the tested progeny.

In view of the regression of weight gains on initial weights, it should be clear that whenever genetic stocks with different initial average weights are stocked together, in communal ponds, differences in their growth rates may be meaningless unless corrected for differences of their initial weights. Variations in environmental or genetic conditions may affect the above regression, therefore a 'correction term' that is appropriate under one set of conditions is not automatically applicable to another.

2.4 The relationship between relative growth rate in communal ponds and yield per unit area in mono-progeny ponds

In addition to implying the necessity of correcting progeny test results for initial weight, the relation between initial weight and weight gain has other, more basic implications. In the progeny tests described above the various tested progenies are introduced into the same ponds (communal ponds) and their relative growth rates compared. However, the property of practical interest is not relative growth rate in communal ponds, but relative yields in separate ponds. These two variables are identical only in the absence of inter-progeny interactions. The existence of such interactions means that one progeny may grow at the expense of another. Such a progeny when grown by itself in a separate pond might not show any increase in yield. Thus the practical value of our progeny testing technique in increasing yields depends on the correlation between growth rate in communal ponds and relative yield in separate ponds.

This crucial relationship was investigated by testing two progenies in separate ponds, as well as in communal ponds, and comparing their relative growth rates with their relative yields. This test has been replicated over a number of years. The results show that the progeny with the faster growth rate in the communal ponds was also the higher yielder in the tests that were conducted in separate ponds. The difference was not significant in any of the individual tests, but for the sum of all of the experiments it was.

In 1963 several ponds were divided into two halves by means of galvanized iron nets. It was shown in a preliminary experiment that the environmental differences between the two halves were very small. Thus, stocking progenies to be tested for relative growth rate in the two halves of the same ponds, gave a sensitive method for determining differences in yield capacity.

Table II

Differences in relative growth rate in communal ponds and yield per unit area of two carp progenies

(The groups tested in 1964 were different from those tested in 1963)

Year	Measured trait	Group 1	Group 2	Difference
1963	Weights gained in communal ponds:			
	(1) Grams per fish	720	592	128 ∓ 26
	(2) Kg per dunam (1,000 m^2)	144.0	118.4	25.6 ∓ 5.2
	Yield in separate ponds[1], (kg per dunam)	122.3	111.7	10.55 ∓ 3.7
1964	Weights gained in communal ponds:			
	(1) Grams per fish	732	544	188 ∓ 43
	(2) Kg per dunam	146.4	108.8	37.6 ± 8.6
	Yield in separate ponds[1] (kg per dunam)	128.7	118.1	10.6 ± 1.9

[1] The two groups of fish were grown separately, in the two halves of ponds divided by nets.

Two tests of this sort were conducted in the divided ponds, one in 1963 and the second in 1964. The results show large and significant differences between the tested groups (Table II). In both cases the progeny with the faster relative growth rate in communal ponds, was also the higher yielder in the divided ponds. The ratio of yield difference in separate ponds, or half-ponds, to relative gained weights in communal ponds was 0.30-0.40. This indicates that about 60-70 percent of the differences between progeny means observed in communal ponds are due to various inter-progeny interactions and the remaining 30-40 percent are due to real genetic differences in yield capacity in mono-progeny ponds. Two basically important points were established by these experiments: i) Considerable genetic differences exist in a trait of prime economic interest, namely, yield capacity in mono-progeny ponds. ii) Ranking of relative growth rate in communal ponds can be used as a criterion of selection for higher yields in mono-progeny ponds.

2.5 The difference in yield capacity between the fastest and the slowest growing individuals of a single spawn

In addition to the genetic and the, so-called, 'temporary environment' components of variation and their interactions, non-hereditary development differences also appear to be of considerable importance. This was demonstrated by testing the difference in yield capacity of the fastest and slowest growing individuals in a single spawn. In this experiment the largest (fast growing 'jumpers') and the smallest (slow growing 'laggards') fractions (each fraction including 15-25 percent of the whole population) were selected from a single progeny, fingerling storage pond. The two groups were reared in separate ponds, and through density manipulations were brought to equal average weights. They were brand-marked and stocked in communal and separate fattening ponds, as illustrated in Fig. 3. The experiment was replicated twice, once in 1961, and the second time in 1962. The values in Fig. 3 are the means for the two years. The results show clearly that despite the equal initial weight of the two fractions, the 'jumpers' grew faster in the communal ponds, and gave higher yields in the separate ponds.

When the weight gained in the mixed ponds is transformed into yield per unit area, the difference between the 'jumpers' and the 'laggards' was 12 kg per dunam. In the separate ponds, the difference was only 6.5 kg per dunam, or 55 percent of the difference observed in the communal ponds. Thus, the difference between the two groups in the communal ponds may be divided into two components. One component is due to the real difference in yield capacity, and the second is due to interactions between the two groups of fish.

Now, the real difference in yield capacity between the two groups is due to genetic differences between them, plus non-hereditary 'developmental differences' or 'pre-test permanent environmental' effects. The experiment, as conducted, does not separate between the two causes, and therefore their relative contributions cannot be estimated directly. Noting, however, that the tested fish were inbred for several generations, and that a high proportion (about 10 percent) of individuals with various visible deformations were found among the 'laggards', we may assume that the relative contribution of the non-hereditary 'developmental effects' was high, and that the additive genetic difference was relatively small.

2.6 Inbreeding and heterosis

We have already mentioned the fact that the asymmetry of the response to up and down selection is reminiscent of the situation in plateaued populations, where additive genetic variation is small or nonexistent, but non-additive genetic sources of variation are important. Other evidence of the importance of non-additive genetic variation is found in the existence of a severe inbreeding depression and a high degree of heterosis.

In order to investigate the degree of inbreeding depression, the experiments illustrated in the first and the third rows of Fig. 1 were carried out. Two unrelated parents (P_1 and P_2) were mated, and a group of their offspring were selected. In the following year, the mating of the original parents P_1 and P_2 was repeated (column 2 under the title 'F_1-repeat'), and served as a control, while the group of selected offspring which were

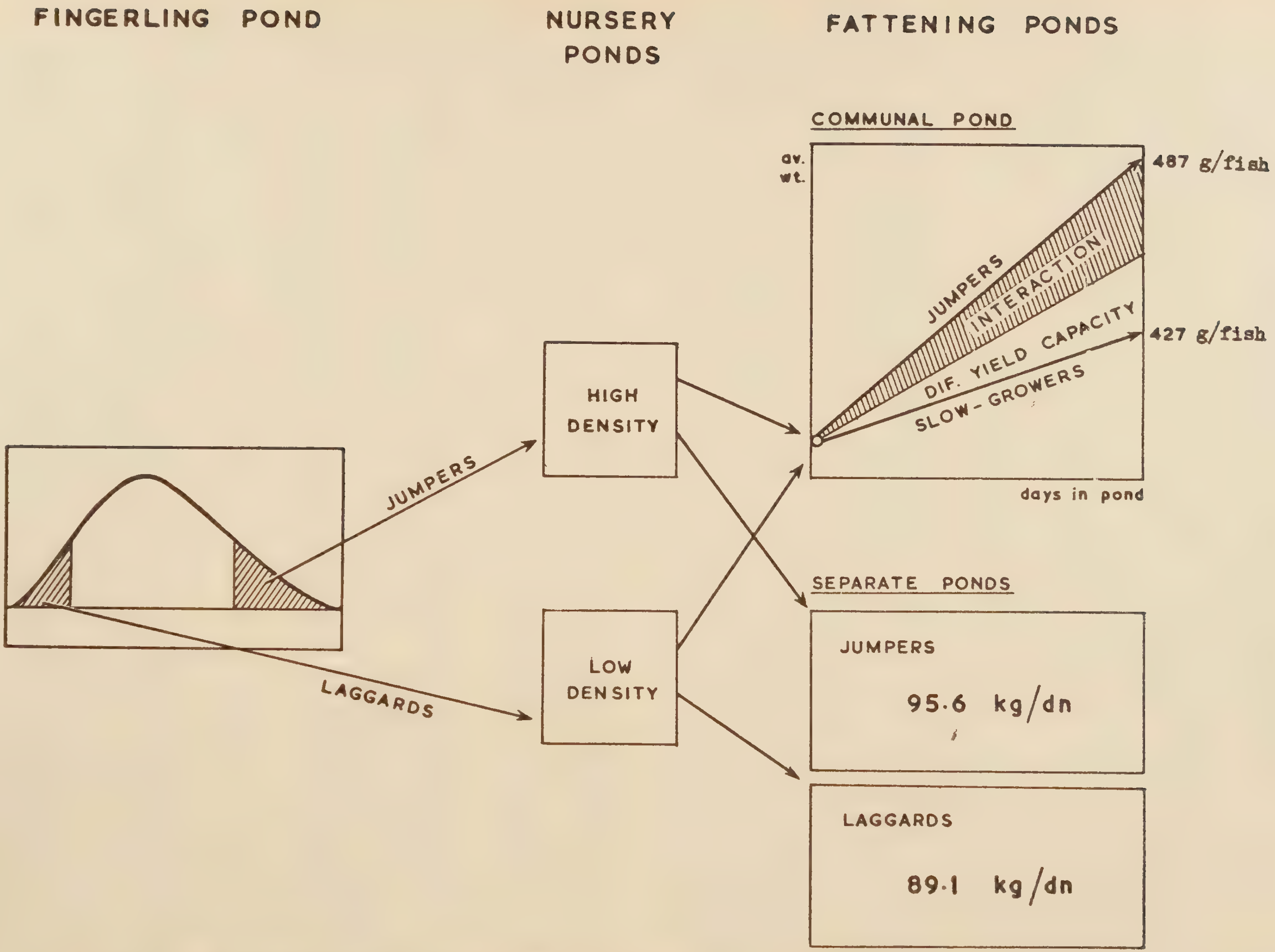

FINGERLING POND
NURSERY PONDS
FATTENING PONDS
JUMPERS
LAGGARDS
HIGH DENSITY
LOW DENSITY
COMMUNAL POND
av. wt.
487 g/fish
427 g/fish
JUMPERS
INTERACTION
DIF. YIELD CAPACITY
SLOW-GROWERS
days in pond
SEPARATE PONDS
JUMPERS
95.6 kg/dn
LAGGARDS
89.1 kg/dn

Fig. 3 The difference in growth rate and yield capacity of 'jumpers' and 'laggards' whose initial weights were equalized

full-sibs, were mass-mated to produce the F_2 generation. In almost every case, when the 'F_1-repeat' was compared with the inbred F_2, a sharp inbreeding depression was found. Thus, our experimental results lead to the conclusion that a single cycle of full-sib mating results in a 10-20 percent depression of growth rate. Other typical effects of inbreeding depression were also found, i.e., reduced viability and a considerable increase in the proportion of individuals with visible abnormalities.

The other side of inbreeding depression, namely, heterosis, was also found as expected. Four examples are illustrated in Table III. Only the first row is, strictly speaking, a comparison between a F_2 (only one generation of inbreeding) and the four-way cross of four unrelated parents (F_1 x F'_1). Hol.A of rows 2 and 3, was an inbred group imported from Holland. The groups gold and blue, were two inbred groups marked with recessive colour mutants.

A comparison of the cross-bred (F_1 x F'_1) with the mean of the two inbreds (F_2 + $F'_2/2$), shows the degree of heterosis, or reciprocally, the degree of inbreeding depression (Table III, last column).

Most of the breeding stocks of carp throughout the world suffer from a high degree of inbreeding. If the experience gained from the Israeli carp population can be generalized, it would seem that the single, and simple step of using unrelated mates for production of commercial fry should improve growth rate and yields in many carp growing areas. The use of cross-bred fish should also improve viability, and increase uniformity.

Table III

Heterosis in Carp. Values in table are corrected average weight gains per fish in grams. (See text for details)

Year	Tested groups		F_2	F_1 x F_1	F_2	$\frac{(F_2 + F_2)}{2(F_1 \text{ x } F_1)}$
	F_1	F_1				
1962	Mis	Beit	469	562	454	0.82
1963	Hol.A	S	499	578	539	0.90
1963	Hol.A	Dor	499	707	600	0.78
1964	Gold	Blue	645	697	516	0.83

3 DISCUSSION OF THE EXPERIMENTAL RESULTS

3.1 Summary of our present state of knowledge of the genetics of growth rate in the carp

The results of the experiments described above are, strictly speaking, valid only for the specific conditions under which they were carried out, i.e. Israeli carp population, grown in the summer and fall seasons, between 30-600 g at densities of 200-250 fish per dunam. Within these conditions the major results of our experiments relating to the genetic architecture of growth rate and yield may be summarized as follows:

(i) There was no detectable response to mass selection for faster growth rate, while selection for slower growth rate resulted in a response expected when heritability is 0.20-0.30.

(ii) Large differences were found in growth rate and yield capacity between means of full-sib families.

(iii) A single generation of brother-sister mating usually resulted in a strong inbreeding depression of growth rate and viability.

(iv) Inter-family cross-breds showed, on the other hand, a high degree of heterosis over their inbred parents.

Table IV

The differences in the contributions of the major variance
components of growth rate to inter-progeny and
intra-progeny variances

(All the fish were grown in a communal pond, and progeny means were corrected for differences in initial weights)

Component of variation	Proportion of component in total variance	
	Between progeny means	Within progenies
Total genetic differences	Large	Medium
a) Additive genetic difference	Small (?)	Small
b) Non-additive genetic difference	Medium-Large	Medium
Random environmental difference	Small	Medium (?)
'Maternal' or 'Developmental' difference	Small	Medium
Inter-fish interactions	Small-medium	Very large

The interpretation of these results, relating to the components of variation of growth rate, is summarized in Table IV. The Table shows that while genetic differences, and perhaps non-additive genetic differences, are the major determinant of the variation between family means in communal ponds, non-hereditary components, in particular inter-fish interactions, determine most of the variability within a spawn.

3.2 The differences in the genetics of growth rate between the carp and other livestock

Our results show that non-additive effects may be of considerable importance in determining genetic differences in the carp population. This situation is in such great contrast to that found in other species that it deserves comment. The additive nature of the genetic differences in growth rate found in other species is apparently the result of the fact that in all of these species the correlation between body weight and reproductive fitness is rather low, hence growth rate has not been subjected to severe natural selection. As a result, additive genetic variation could be accumulated and maintained. The situation is rather different in the carp. In this species, body weight is highly correlated with egg number in the females and sperm number in the males. It is also correlated with egg size in the females, and egg size appears to be a major component of fingerling viability in the critical period following hatching.

Thus, it would probably be correct to assume that body weight in the carp is the most important component of reproductive fitness. This puts it in the same category of typical 'reproductive characters' such as egg number in poultry, litter size in pigs, etc. Such traits have been found to behave in a way similar to that of growth rate in the carp, i.e., low heritability and poor response to positive selection.

4 APPLICATION OF THE GENETIC KNOWLEDGE GAINED TO CARP BREEDING

4.1 Breeding plans

Accepting the information in Table IV as the best we have at the present time, it is appropriate to apply this knowledge to the design of effective breeding programs. In view of the strong inbreeding depression, heretosis and lack of response to mass selection for faster growth rate in carp, it would seem that the basic feature of any effective breeding program should be the production of selected cross-bred commercial fingerlings. Selection of the parental lines, and the selection within them, should therefore be aimed primarily at improvement of cross-bred performance rather than parental line performance itself.

Finding a pair of lines that produce a superior cross-bred offspring involves testing a large number of inbreds for cross-bred performance. In any one year as many combinations of inbreds may be tested as the available facilities permit. The parents of the best combinations may be used immediately after termination of the progeny tests for the production of commercial cross-bred fry for fattening. The following year a new set of combinations may be tested. If the best of the new set are as good, or superior to the best of the previous sets, they can be added to, or even substituted as a source of commercial fry.

The following method of screening for new combinations has been adapted by the Israeli Fish Breeders Union. Each year about 20 pairs of fish are spawned and progeny tested. The tested pairs may include those that excelled in previous years. They may also include a group of full-sibs (treated as a single parent) of a superior progeny of the previous year, mass spawned with an unrelated mate.

The faster growing individuals of the best progenies are selected to serve as parents of cross-bred fry for the fattening ponds. The remaining progenies are culled. The same process is repeated with new pairs each year.

As the number of tested combinations increases, the probability of finding a new combination that is superior to the best of the combinations tested earlier, becomes quite small, and further improvement requires selection for combining ability within the best parental lines. The selection procedures that meet this requirement are the so-called 'recurrent selection'(RS) and 'reciprocal recurrent selection' (RRS). The basic feature of the above selection procedures, distinguishing them from other selection procedures is that the pure-bred parents are selected on the basis of the performance of their cross-bred half-sibs rather than on the basis of their own performance (Fig. 4).

In a breeding program of fish, it is essential that the purity of the stocks is well maintained. This point cannot be over-emphasized, as the large reproductive potential of the carp enables a single 'infiltrator' to nullify the results of several years of breeding. Our experience has shown that contamination of stocks, through infiltration of fish from one pond to another, cannot be eliminated under practical circumstances. This is particularly true in experimental stations or breeding farms which comprise many adjacent small ponds, stocked by different groups of phenotypically indistinguishable fish. Our solution to this problem is to mark the parental lines with genetic markers. In our programs we plan to use three recessive body colour mutants, gold, blue and grey. All three have negative effects on growth when in homozygous conditions. They do not seem to have adverse effects in heterozygous condition, and some indications suggest that the heterozygote may even be over-dominant in respect of growth rate relative to the homozygote normally coloured fish.

An important disadvantage of the RRS method, or for that matter any other selection procedure that is based on family selection or progeny testing, is that it increases inbreeding in the parental lines. Inbreeding means loss of genetic differences, and without genetic variability selection cannot be effective. An appropriate way of preventing this

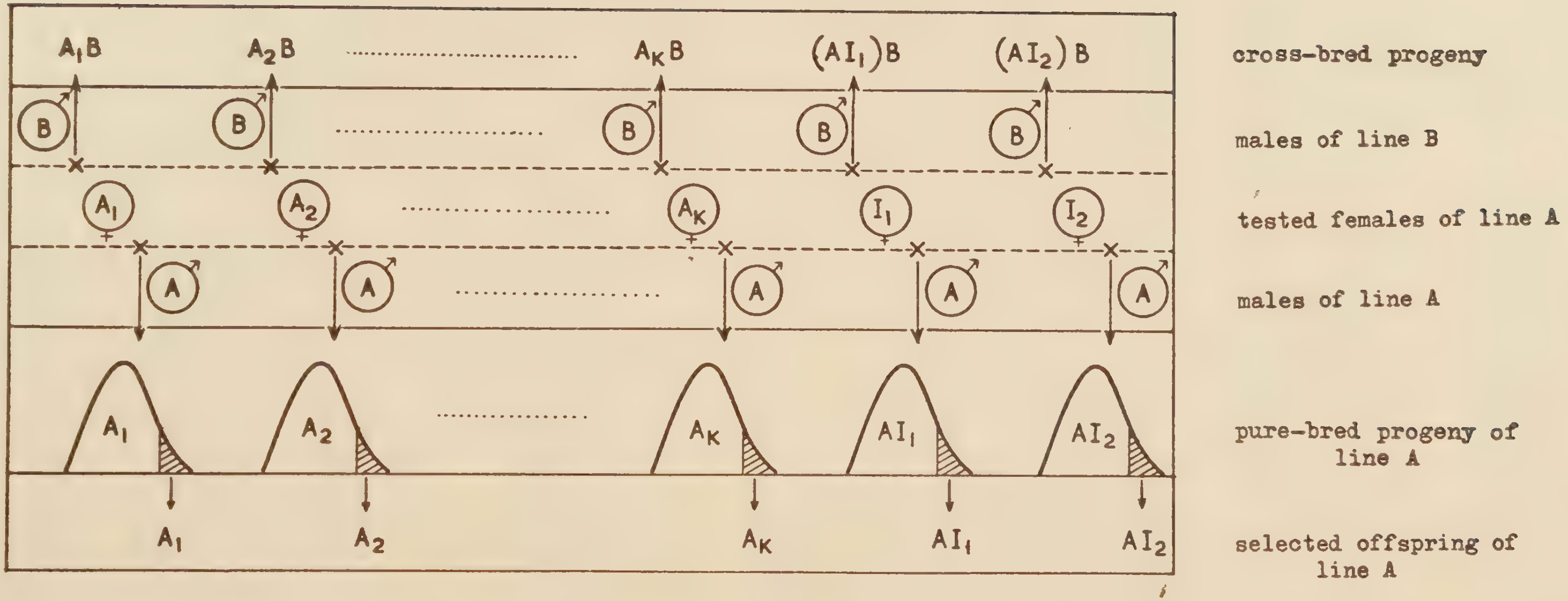

A₁B
A₂B
AₖB
(AI₁)B
(AI₂)B
cross-bred progeny
B ♂
males of line B
A₁ ♀
A₂ ♀
Aₖ ♀
I₁ ♀
I₂ ♀
tested females of line A
A ♂
males of line A
A₁
A₂
Aₖ
AI₁
AI₂
pure-bred progeny of line A
A₁
A₂
Aₖ
AI₁
AI₂
selected offspring of line A

Fig.4 Schematic presentation of a combination of Recurrent Selection (of females of the parental line A) plus mass selection within the pure-line. (I_1 and I_2 represent two tested immigrants of the 'open gene pool' of the parental line A)

hazard may be the use of what may be termed the 'open gene pool' system. This system as related to an RRS program involves the maintenance of genetically marked 'reserve gene pools' for each one of the two parental lines. Each cycle of progeny testing may include a small proportion of the individuals from the 'reserve gene pools'. If the progeny testing results show that one or more of the 'gene pool' immigrants produced superior cross-bred progeny, its pure-bred progeny may be incorporated into the pure-bred parental line.

This method is relatively simple and safe, since immigrants are incorporated into the selected parental lines only through the sieve of progeny-testing. Theory indicates that even a small proportion of immigrants is sufficient to maintain a sufficient degree of genetic variability for selection. Furthermore, the use of the 'open gene pool' system will reduce the otherwise overwhelming importance of the choice of the original lines. If the originally selected parental lines remain closed, one is never certain whether outside genetic material of superior quality has not been overlooked. This hazard is greatly reduced by the 'open gene pool' system because a provision is made for a continuous testing of genetic material from outside sources.

When a breeding program has been established, its efficiency as measured by rate of genetic improvement is a function of generation interval. In warm climates where one-year-old fish spawn regularly, relative progress may be fast. On the other hand in temperate and cold climates, where traditional methods require three to four years for maturation of fish, generation interval may prove to be a serious block to rapid genetic progress, as well as to genetic experimentation in general. A partial solution for this problem may be found in the maintenance of selected fish under 'hot house' conditions throughout the winter.

A more promising solution to the same problem is to carry out the breeding of parent stocks, for use in cold climates, in tropical or sub-tropical regions. In order to ensure adaptation to the cold climate where the commercial fish will eventually have to grow, the progeny tests may be performed in the region for which the breeding is done.

4.2 Selection for an ideal 'body conformation'

Selection for an ideal body conformation has little place in our breeding program, while it does seem to play an important role in many carp growing areas; this procedure is justified only when conformation has a high correlation with characters of economic value. A search of the literature did not reveal any experiment that demonstrated a correlation between body measurements and growth rate in the carp. Stegman (1958) showed zero correlation between several body measurements and growth rate in carp. In our progeny tests, body measurements of the tested groups were taken routinely and their relationships to growth rates have been studied. These studies (unpublished) did not reveal any correlation between the measured characters and growth rate.

Body composition characters may be correlated with some measurements of conformation. Selection for specific conformation may be useful in this respect. However, such selection will be justified only if the economic importance of the 'carcass quality' trait has been clearly demonstrated, and its genetic correlation with a measured conformation shown to be reasonably high.

4.3 Introduction from outside as means of genetic improvement

The method of genetic improvement through importation of new stocks may follow four alternative courses (Moav, 1964):

(i) Replacement. When the imported breed is greatly superior to the local breeds, the latter may be completely substituted by the former.

(ii) Up-grading. When the overall performance of the imported breed is higher than the local but the latter is superior in some traits (such as adaptation to local climatic conditions, or resistance to local parasites and diseases) or when replacement is too expensive, hybridization, followed by successive back-crosses to the imported breed may result in a combination of the high performance of the imported stock and the specific advantages of the local breed.

(iii) When the F_1-hybrid between the local and imported breeds is superior to its two parents, the two parents may be maintained as pure lines for production of commercial hybrids.

(iv) When the imported stock and its F_1-hybrids are inferior to the local breed in overall performance or in any particular trait, the imported stock may serve as a source of new genetic variability for the local gene pool. The technique of obtaining this result is the direct opposite of 'up-grading'. The hybrid between the two is back-crossed to the local breed and each successive back-crossing is accompanied by selection.

In fish, introduction as means of genetic improvement should probably follow the third and fourth courses. The testing of the imported stocks can be integrated into 'open gene pool'.

It should be noted that testing of the immediate immigrants, or even their first offspring generation born in the new location, may be misleading. It is quite possible that an imported stock which is highly superior in yield capacity is sensitive to local climate, diseases or parasites. This may result in its poor performance in spite of a superior genotype. It follows that if a true evaluation of the potential improvement through the use of a particular import is desired, it should undergo at least one or two generations of natural selection under local conditions.

5 CHALLENGE FOR THE FUTURE

The main challenge for future research into the genetic basis of carp breeding lies in the fact that the breeding program envisaged here does not make use of the extremely large selection differential, unthinkable in other livestock, made possible by the high reproductive potential of carp. The major reason is that under the environmental conditions of commercial fish ponds, mass selection for faster growth does not seem to yield a detectable response.

Tapping the high reproductivity of carp requires basic and thorough research into the causes of variation in growth rate between individuals that occupy the same pond. Particular emphasis should be given to the study of the components of the genetic variance, to intra-pond-inter-fish interactions, and genotype x environment interactions.

There is still a possibility that our notions of the lack of additive genetic variation are exaggerated. Also, it may be possible to introduce additive genetic variation by appropriate crossing with outside stocks, or by mutagenic procedures. We must be alert to the possibility that selection for traits other than growth rate, may also increase the economic value of carp, e.g., selection for high protein content, or for adaptation to brackish or polluted waters. Finally, various technical means for simplifying and increasing the efficiency of breeding programs should be investigated. Artificial spawning and use of small containers for growth experiments should probably get priority in this category.

6 ACKNOWLEDGEMENTS

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IV/R-3

BREEDING AND SELECTION OF CULTIVATED WARM-WATER FISHES IN ASIA AND THE FAR EAST - A REVIEW

by

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Abstract

Indian and Chinese carps, the mullet and the milkfish are the most important warm-water pond fishes cultivated in Asia and the Far East. While certain carps and other fishes of minor importance spawn in ponds, the widely cultivated species do not breed in captivity.

Indian carps, however, are known to breed in special type of ponds known as 'bundhs' where riverine conditions are simulated. A better and more dependable technique has recently been evolved for inducing the breeding of these and Chinese carps by injection of fish pituitary hormones. This technique is now used in fish culture in India, China and Taiwan for raising seed of these carps commercially.

Although initial success has been achieved in spawning mullets by hormone treatment, proper breeding and hatching techniques are yet to be developed. Also, very little is known of the spawning habits of the milkfish and the eel which do not attain maturity or spawn in confined waters. Natural habitat is the only source for their seed.

Improvement of stock by selective breeding and hybridization is vitally important for better production of fish. Inducing sterility in certain types of fish is necessary for proper manipulation of stock in fish culture.

The urgent need for systematic research on controlled reproduction and genetic selection of fish and also for proper training of personnel, extension and popularization of the new techniques among fish farmers is emphasized.

ELEVAGE ET SELECTION DE POISSONS D'EAU TIEDE EN ASIE ET EN EXTREME-ORIENT - ETUDE GENERALE

Résumé

En Asie et en Extrême-Orient, ce sont les carpes indiennes et chinoises, le mulet et le chanos qui constituent les principales espèces de poissons élevées en étang à température élevée. Bien que certaines carpes et autres poissons de moindre importance fraient en étang, les espèces les plus répandues ne se reproduisent pas en captivité.

On sait toutefois que les carpes indiennes pondent dans des étangs de type spécial connus sous le nom de "bundhs" et qui reproduisent des conditions analogues à celles régnant en rivière. On a mis au point récemment, pour les carpes indiennes et chinoises, une technique meilleure et plus sûre de reproduction artificielle provoquée par l'injection d'hormones tirées des glandes pituitaires de poisson. Cette technique est à présent utilisée en Inde, en Chine et à Taiwan pour l'élevage commercial de ces carpes.

Bien que les premiers essais de reproduction artificielle de mulets par traitement aux hormones aient donné des résultats encourageants, on n'a pas encore mis au point des techniques satisfaisantes d'incubation et d'alevinage. On sait également peu de chose sur les habitudes de frai du chanos et de l'anguille qui n'atteignent pas la maturité sexuelle et ne se reproduisent pas dans des plans d'eau fermés. On ne peut se procurer leurs oeufs que dans le milieu naturel.

Pour améliorer la production de poisson, il est essentiel pratiquer la sélection et l'hybridation. Avec certaines espèces il est nécessaire d'avoir recours à la stérilité induite si l'on veut contrôler les effectifs en pisciculture.

L'auteur souligne qu'il est urgent de procéder à des recherches systématiques sur la reproduction contrôlée et la sélection génétique des poissons ainsi que de former du personnel compétent et de diffuser les nouvelles techniques parmi les pisciculteurs.

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CRIA Y SELECCION DE PECES CULTIVADOS EN AGUAS TEMPLADAS EN ASIA Y LEJANO ORIENTE

Extracto

La carpas indias y chinas, el mújol y el sabalote son los peces de estanques de aguas templadas más importantes que se cultivan en Asia y el Lejano Oriente. Aunque algunas carpas y otros peces de menor importancia desovan en estanques, las especies que más se cultivan no se crían en cautividad.

Sin embargo, las carpas indias se sabe que crían en tipos especiales de estanques llamados "bundhs" en los que se imitan las condiciones fluviales. Recientemente se ha ideado una técnica mejor y más segura provocando la reproducción de estas carpas y de carpas chinas mediante la inyección de hormonas de pituitaria. Esta técnica se emplea actualmente en la piscicultura en la India, China y Taiwán, con objeto de obtener crías de estas carpas en cantidades comerciales.

Aunque se ha logrado un éxito inicial en lo que respecta al desove de los mújoles mediante un tratamiento hormonal, sin embargo todavía no se han desarrollado técnicas adecuadas de cría y de incubación. Del mismo modo, se sabe muy poco acerca de los hábitos de desove de los sabalotes y las anguilas que no alcanzan la madurez o que no desovan en aguas cercadas. El habitat natural es la única fuente de su reproducción.

El mejoramiento de las poblaciones de peces por medio de la cría selectiva y de la hibridación selectiva es fundamentalmente importante para mejorar la producción de peces. Es necesario provocar la esterilidad en ciertas clases de peces para poder manipular adecuadamente a las poblaciones en la piscicultura.

Se pone de relieve la apremiante necesidad que existe de llevar a cabo investigaciones sistemáticas sobre la reproducción controlada y la selección genética de los peces, así como de capacitar convenientemente al personal, y ampliar y popularizar las nuevas técnicas entre los piscicultores.

1 INTRODUCTION

The major carps of China and India form the main economic food fishes raised in countries of Asia and the Far East. As these fishes spawn naturally in the large rivers when they are in flood, considerable difficulties are experienced by the fish farmers in obtaining sufficient quantities of pure fish seed for stocking ponds. With the first success of pond breeding of major carps in India by injections of fish pituitary hormones (Chaudhuri and Alikunhi 1957; Chaudhuri 1960; Alikunhi et al., 1960) an alternative dependable method of obtaining pure fish seed was ensured. Subsequently similar techniques were also successfully developed in artificial breeding of Chinese carps (Aliev, 1961; Alikunhi et al., 1963a and b; Tang et al., 1963). The Indian carps also breed in 'bundhs' which are special types of ponds subjected to flooding from adjoining extensive catchment areas (Hora et al., 1945).

The breeding techniques of the other important cultivated species which spawn in ponds have been well developed. The methods adopted in different regions of South-East Asia, however, vary considerably (Hora and Pillay, 1962). Selection of proper breeders for breeding purposes is no less important since success in spawning and obtaining healthy progeny depends largely on proper selection of brood fish. Selective breeding leads to improvement of stocks; the new strains or hybrids developed having better cultural qualities. Hybridization for producing hardier, disease-resistant and improved varieties of fishes (Baldwin, 1956; Scott, 1956; Buss and Wright, 1958; Chaudhuri, 1959a) has assumed increasing importance in recent years.

In the present paper an attempt has been made to bring together the information available on the methods developed in the selection and breeding of the warm-water cultivated species in Asia and the Far East.

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2 LIST OF IMPORTANT WARM-WATER FISHES CULTIVATED IN ASIA AND THE FAR EAST

The most widely cultivated fish in the region are the quick growing, non-predatory carps belonging to the family Cyprinidae. Even though the culture of piscivorous fishes is generally less economical, some predatory fishes are cultured in certain areas, mainly on account of consumer preference. In addition, a number of exotic fishes have been introduced and marine and brackish-water fishes transplanted into fresh-water ponds by the fish culturists (Jones and Sarojini, 1951; Schuster, 1952a; Alikunhi et al., 1952).

A classified list of the popular pond fishes cultivated in Asia and the Far East is given below, showing the distribution and habitat of each species (Ling, 1955; Hora and Pillay, 1962).

Scientific name	Family	Distribution	Natural habitat	Countries where cultivated
1. *Catla catla*	Cyprinidae	India, Pakistan Burma	Rivers	India, Pakistan, Burma, Ceylon
2. *Labeo rohita*	"	"	"	"
3. *Cirrhina mrigala*	"	"	"	"
4. *Labeo calbasu*	"	"	"	"
5. *Hypophthalmichthys molitrix*	"	China	"	China, Japan, Hong Kong, Taiwan, Malaysia, Thailand, India, Ceylon
6. *Ctenopharyngodon idella*	"	"	"	China, Japan, Hong Kong, Taiwan, Malaysia, Thailand, India, Ceylon, Vietnam, Pakistan
7. *Aristichthys nobilis*	"	"	"	China, Japan, Hong Kong, Malaysia, Thailand, Vietnam, Taiwan
8. *Mylopharyngodon piceus*	"	"	Ponds, rivers and lakes	China, Hong Kong, Malaysia, Taiwan, Japan, Thailand, Vietnam
9. *Cirrhina molitorella*	"	"	"	"
10. *Cyprinus carpio*	"	Originally China and Vietnam. Now distributed all over the region	Lakes and rivers	Almost all the countries of the region
11. *Puntius javanicus*[1]	"	Indonesia, Thailand, Vietnam	"	Indonesia, Thailand, Malaysia

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[1] Since *P. javanicus* is better known among fish culturists, the name is used in preference to *Puntius gonionotus*.

Scientific name	Family	Distribution	Natural habitat	Countries where cultivated
12. *Osteochiilus hasselti*	Cyprinidae	Indonesia, Malaysia, Thailand	Lakes, rivers	Indonesia, Malaysia Thailand
13. *Trichogaster pectoralis*	Osphronemidae	Thailand, Cambodia, Vietnam	Rivers, shallow lakes	Thailand, Malaysia, Indonesia, Pakistan, Ceylon
14. *Osphronemus goramy*	"	Indonesia, Thailand, Malaysia, Cambodia, Vietnam	Rivers, shallow lakes, swamps	Indonesia, Thailand, Ceylon, India, Malaysia
15. *Helostoma temmincki*	Helostomidae	Thailand, Malaysia, Indonesia	"	Thailand, Malaysia, Indonesia, Ceylon
16. *Tilapia mossambica*	Cichlidae	South East Africa, introduced to most of the Asian countries	Fresh-water and brackish-water rivers	Most of the countries in the region
17. *Etroplus suratensis*	"	India, Pakistan, Ceylon	Fresh- and brackish-water lakes	India, Ceylon
18. *Chanos chanos*	Chanidae	Most countries of Asia and Far East	Marine and brackish water	Philippines, Indonesia, Taiwan, India, Thailand
19. *Mugil cephalus*	Mugilidae	"	"	China, Taiwan, Hong Kong, India

Besides the above, the following species of fishes are also used for pond culture but most of these are cultured mainly in the region where they naturally occur. They are: *Cirrhina cirrhosa*, *Barbus* (*Lissochilus*) *hexagonolepis*, *Labeo fimbriatus*, *Carassius carassius*, *Parabramis pekinensis*, *Puntius orphoides*, *Mugil tade*, *Mugil dussumieri*, *Liza corsula*, *Pangasius* spp., *Anguilla japonica*, *Ophicephalus* spp., *Anabas testudineus*, *Clarias batrachus*, *Heteropneustes fossilis* and *Lates calcarifer*.

3 BREEDING REQUIREMENTS AND BREEDING HABITS OF CULTIVATED SPECIES

The breeding requirements of some important cultivated species are quite complex and our present knowledge of the optimum ecological conditions for their spawning is inadequate.

Fabricius (1950) studied the different stimuli for the spawning activities of fish and concluded that these were activated by an inherited neural releasing mechanism peculiar to each species in which various external as well as internal stimuli cooperate by heterogeneous summation and the release is usually brought about by several different combinations of stimuli. Of the external factors temperature and light are considered to be the most important ones influencing maturity and spawning in fishes (see Harrington, 1950; Shiraishi and Takeda, 1961; Craig-Bennett, 1930; Hoover and Hubbard, 1937; Allison, 1951). Rain, flood, increase in dissolved oxygen content and pH of water are also believed to be important external factors responsible for spawning (Khan, 1945; Mookerjee, 1945b). According to Swingle (1956) fishes probably excrete into the water a hormone-like substance or substances which may reduce or prevent reproduction. Because of this "repressive factor", certain fishes do not spawn when kept overcrowded, but spawning occurs when they are released in fresh water. Influence of population density on the reproduction of fish has been observed by Kawajiri (1949) and in Europe carp is bred by releasing brood fishes in the fresh water of "Dubisch ponds". (Schaeperclaus, 1933). Of the internal factors, endocrine secretions, especially that of the pituitary gland is believed to induce ovulation and spawning in fishes (see Pickford and Atz, 1957). This secretion is again influenced by external factors like rain, light, temperature, etc. "The external environment mediates its effect on the endocrine system through the pituitary" (Hoar, 1957). The sexual play of brood fishes under optimum conditions also appears to stimulate secretion of these hormones.

Breeding habits differ considerably in different groups of fishes. According to their breeding habits, the important cultivated pond fishes of the region may be grouped into three distinct groups.

3.1 - Group I

This group includes fishes such as *Cyprinus carpio* (common carp), *Tilapia mossambica* (tilapia), *Osphronemus goramy* (gourami), *Trichogaster pectoralis* (sepat siam), *Etroplus suratensis* (pearl-spot), *Helostoma temmincki* (kissing gourami), *Osteochilus hasselti* (nilem), *Puntius javanicus* (tawes), *P. orphoides* (mata merah), *Ophicephalus* spp. (murrels) etc. which breed in ponds.

Parental care is observed in tilapia, sepat siam, pearl-spot, gourami and the murrels. Tilapia (male) makes a circular depression at the pond bottom in which the female lays eggs. The fertilized eggs are picked up by the female and kept in the mouth where further development and hatching take place (Vaas and Hofstede, 1952). The gourami builds a nest out of grass and weeds on the pond margins, while the male sepat siam builds a foam nest in which the eggs are laid. The pearl-spot attaches eggs in layers to hard substrata. The murrels build nests with vegetation near the margin of ponds in shallow waters and the parent fish guard the fry.

Other cultivated species belonging to this category such as the common carp, nilem, tawes, mata merah and kissing gourami do not show parental care but breed in ordinary ponds. Nilem and tawes spawn when well-oxygenated running water is supplied to the ponds. While the eggs of nilem and tawes are demersal and non-adhesive, those of kissing gourami float on the surface and the mata merah eggs are adhesive. The common carp also breeds in ordinary ponds but the intensity of breeding is accelerated when they are released in fresh water. The adhesive eggs are attached to aquatic plants or on other objects. Majority of the fish belonging to this group breed more than once or several times in a year.

3.2 Group II

Fishes of this category do not ordinarily spawn in ponds but breed in flooded rivers and adjoining areas. Indian and Chinese carps belong to this group. Indian carps are known to breed in 'bundhs' which are specially designed ponds receiving inflow of fresh rain water (Das, 1917), but Chinese carp were believed to breed only in their natural habitats in China. Kuronuma (1954) reported the breeding of silver and grass carps in the Tone river of Japan. Tang (1960) has also obtained fry and fingerlings of these carps in the Ah Kung Tian reservoir in Taiwan.

However, in recent years, both these Indian and Chinese carps could be induced to breed by injection of fish pituitary hormones (Chaudhuri and Alikunhi, 1957; Chaudhuri 1960; Aliev, 1961; Alikunhi *et al.*, 1963a and b; Tang *et al.*, 1963) as already mentioned and the technique has been further developed to obtain commercial production of fish seed(Chaudhuri, 1963; Tang, 1965; Chaudhuri *et al.*, 1966).

3.3 Group III

This group includes mainly marine or brackish-water species, which do not spawn in ponds or so far could not be induced to spawn in ponds. *Chanos chanos* (milkfish), *Lates calcarifer* (cock-up), *Mugil* spp. (mullets) and *Anguilla japonica* (eel) come under this group. The milkfish breeds in the sea and the eggs are pelagic. The species has not been observed so far to attain maturity or to spawn in ponds or in other confined waters. The grey mullet (*Mugil cephalus*) also does not breed in ponds or in estuaries and is believed to spawn only in the sea. The fresh-water mullet (*Liza corsula*) breeds in the fresh waters of rivers (Pakrasi and Alikunhi, 1953) and the cock-up in brackish-water rivers, creeks or lagoons. The eel spawns only in the deep sea. The young ones of most of the above mentioned species are collected from the sea coast and estuaries for stocking in ponds.

4 BREEDING TECHNIQUES AND SELECTION OF BREEDERS

4.1 Pond breeding

The breeding requirements of fishes that readily spawn in confined waters are comparatively simple. The fish breeder has mainly to provide proper facilities so as to ensure proper attachment of eggs, building of nests, etc. Selection of breeders is of great importance and a good deal of practical experience is required to find out the characters to be taken into consideration for the choice of breeders. Hora and Pillay (1962) have compiled existing information on the pond breeding of important cultivated species of the Indo-Pacific countries.

4.1.1 *Cyprinus carpio*

Unlike in Europe and other Western countries where the common carp breeds only in spring, in most of the countries of Asia and the Far East the fish breeds almost throughout the year and the techniques of breeding vary considerably in different areas.

4.1.1.1 Breeding methods

In Indonesia a highly developed technique for the breeding of common carp has been evolved. Hofstede and Ardiwinata (1952), Saanin (1955) and Hora and Pillay (1962) have described in detail the various specialised methods developed in different parts of Indonesia. Of the several methods, the more important ones are the Sundanese method, and Rantjapaku method which are described below.

Sundanese method. This method is the most popular one and is extensively used in West Java and many other parts of Indonesia. Separate ponds are maintained for the brood fish, and for spawning and hatching purposes. The breeders are segregated according to sex and either kept in separate ponds or in some cases in the same pond separated by bamboo screens. The brood fish are fed with artificial feeds like rice bran, kitchen refuse, etc. Spawning ponds are elongated and usually 25 to 30 m^2 in area having a hard bottom (not rocky) devoid of mud or silt. The pond is dried for a few days and then filled with oxygen-rich fairly clear water. In case of turbid water it is first passed through a sedimentation tank and then introduced into the spawning pond. The depth of water in the ponds is maintained at 50 to 70 cm. For the attachment of eggs special type of egg-mats known as kakabans are used. The kakabans are an improvement over the old practice of using weeds as egg collectors. Hair-like black fibres of indjuk (Arenga spp.) are thoroughly cleaned and arranged in thin layers 50 to 70 cm in length breadthwise and pressed between two bamboo slats 4 to 5 cm wide and 150 to 200 cm in length and nailed together on the two sides.

In the spawning pond the egg mats are placed transversely on a long pole close to each other and they float at the surface of water; the long pole being held in between two posts fixed at both ends. The weight of the kakabans keep them slightly under the water surface. Usually 5 to 8 kakabans are supplied per kg weight of the female breeder. The female attaches the eggs to the lower surface of the egg mats. Periodically these mats are inspected by the fish farmer who turns them over as and when the lower surface is covered with eggs.

The mats with eggs are then transferred to hatching ponds, the area of which is generally 20 times that of the spawning pond. The hatching pond is also kept dry for some days and filled with water a few days before the spawning takes place. The mud sticking to the kakabans is carefully washed and removed and then the mats are placed transversely on floating bamboo poles at a distance of 5 to 8 cm from each other. Some wooden poles or banana stems are placed on these poles so as to keep the egg mats about 8 cm below the water surface. The hatching pond has a number of outlets at different levels to regulate the out-flow of water and gradual draining is effected, when the fry are collected in sieves.

Tjimindi method. This method is more or less like the Sundanese method excepting that the spawning pond is constructed at one corner of the large hatching pond being separated from the latter by a temporary dyke. After the completion of spawning the spawners are led into the hatching pond through a hole in the dyke which is closed again. When the fry are one week old the dyke is cut and the fry are allowed to move into the hatching pond proper.

Rantjapaku method. This resembles the Tjimindi method excepting that in this the bottom of the spawning compartment is constructed at a higher level than the main hatching pond and is made of sand and gravel. The dyke is constructed of stones. The small gaps between the stones enable the fry to pass but not the parents. Instead of kakabans, newly cut floating grass is used for the attachment of eggs.

The Central Sumatra method. In this method, which is only seldom employed, very small spawning ponds (5 m^2) are used, and instead of kakabans indjuk fibres are scattered on the water surface. The spawners are removed after spawning is over and the fry are collected when only five days old.

In recent years a slight improvement has been introduced in the eastern part of West Java where bigger spawning ponds having sand and gravel bottom are used and kakabans as egg collectors are provided.

Besides the above mentioned methods, the 'Dubisch method' is also practised in many parts of Indonesia, especially in Central and East Java.

In Japan, common carp culture is a fairly important industry (Isaev, 1959) and highly developed techniques are employed as in Indonesia. Large-scale breeding of common carp is done for the supply of fry for culture in paddy fields. The breeding technique is more or less similar to the improved Indonesian methods already described.

In China, submerged aquatic weeds like Ceratophyllum, Myriophyllum and water hyacinth are generally used for the attachment of eggs. Square bamboo frames are placed in order to keep the weeds together and in place (Hora and Pillay, 1962). In general, the Indonesian technique of breeding is followed in Thailand, Malaysia and Vietnam. Kakabans are used as collectors for eggs but instead of the fibre of the Arenga spp. other fibres such as used for manufacturing ropes, brushes, etc. are used.

In Taiwan, traditional methods are still in vogue for the breeding and cultivation of common carp (Tubb, 1963). In the Philippines, the common carp has been introduced in recent years and the species is now established in several fresh-water lakes and is also reared in fish ponds. It has been reported that the common carp has been successfully induced to breed by pituitary hormone injection (Rabanal-Personal communication, 1965). In Ceylon, Cyprinus carpio culture has lately developed considerably and thousands of fingerlings are produced in the hatcheries of the Fisheries Department and are stocked mainly in the major irrigation reservoirs (Anon., 1963).

In India, the original Prussian stock of common carp was introduced first in the Nilgiri Hills and till recently was believed to breed only in cold waters at high altitudes. However in recent years the strain could also be bred in the warm waters of the plains. In 1957, a warm-water strain was introduced from Bangkok, which has been bred successfully at the Central Inland Fisheries Research Sub-station at Cuttack and distributed all over India where it is at present stocked and cultivated. The breeding technique developed at the Sub-station (Alikunhi, 1960; Chaudhuri, 1964a) is described below.

The fish breeds throughout the year with the peak periods in January-March and July-August. It sexually matures in 6-8 months, the minimum size of maturity being 15-20 cm and 80-170 g. The same fish can be bred 4 to 5 times in a year. The male and female breeders are segregated a few months before spawning and are regularly fed with artificial feeds like oil cake and rice bran. No separate spawning ponds are necessary. The fishes can be bred successfully in cement cisterns with tap or pond water or in hapa (cloth container) fixed in ponds. With one big female breeder usually a number of smaller male breeders are introduced ensuring that the total weight of the males equals that of the female. The breeding hapa is made of thin cloth, stitched in the shape of an inverted mosquito net with tapes at the margins and fixed by means of bamboo poles in the marginal area of ponds. A thin-meshed cover is put over the hapa to prevent escape of breeders after their introduction. The size of a breeding hapa varies from 1.8 m x 0.9 m x 0.9 m to 3.6 m x 1.8 m x 0.9 m depending on the size of breeders. Common submerged aquatic weeds like Hydrilla and Najas are generally used as egg collectors although kakabans made of coconut fibres are also used occasionally. About 4.5 kg of weeds are provided for the breeding of a female weighing 3 to 4 kg. Breeders are released in the evening and the hapa are examined for eggs by the next morning and extent of spawning and percentage of fertilization is ascertained. Based on this, the weeds with attached eggs are thinned out and distributed to a number of hatching hapa. Hatching hapa are also cloth containers like the breeding hapa but without the top cover. The usual size is 1.8 m x 0.9 m x 0.9 m. The incubation period is about 2 to 3 days. After another 2 days the fry are collected from the hapa and stocked in ponds. This technique is more or less followed all over India. In the eastern parts of India however, breeding of Cyprinus in ponds with water hyacinth as collectors is also practised.

4.1.1.2 Selection of breeders

Proper selection of breeder is of utmost importance in successful fish breeding. The fish breeders of these countries have developed their own criteria in the choice of spawners from the practical experience gained by breeding carps for years. In selecting good breeders usually factors like the shape of the body, fecundity, age and health are taken into consideration. Through selective breeding quick growing strains are also produced, which are selected as breeders.

Alkhunis(1956) has compiled information on improving the breed of carp especially from Soviet literature and from the work of Israeli and other workers. The criteria for selection according to him should be weight, body shape, fin development, proper shape of lateral line, number of scales and their distribution on the body and proper ratio between width and length.

Sexes are usually distinguished by the examination of the genital opening. Only the larger and older males develop some tubercles on the sides of the head and roughness on the pectoral and pelvic fins. In fully mature breeders however, the milt and a few eggs could be extruded by giving gentle pressure on the abdomen.

The Indonesians select female breeders of $1\frac{1}{2}$ years but preferably of 2 years age, weighing 1 to 2 kg. The males are usually $1\frac{1}{2}$ years of age and weighing roughly 1 kg. These selected breeders are bred once in every 3 months for about 4 years. Sometimes a number of smaller males are introduced with a bigger female but the ratio of male and female is always maintained as 1:1 by weight. The main criteria followed by average Indonesian fish culturists are: (a) big fairly soft belly, the lower side broad and flattened so that the fish can stand on its belly, (b) great body depth and high and strong caudal peduncle, (c) relatively small head and pointed snout, (d) rather large scales in regular rows and (e) genital opening situated far back (Hofstede and Ardiwinata, 1952).

The central mid-ventral position of the last scale before the genital opening is also considered by some as the sign of a good spawner. The mode of attaching eggs to the _kakabans_ by a female is often taken into consideration.

In Indonesia and also in Japan, several coloured varieties and strains have been produced by selective breeding. Some of the Indonesian strains are: (a) mas punten and ikan taja (olive green), (b) mas merah (red), (c) sinjonja (yellow), and (d) mas kumpai (long-tail variety). Besides these, there are varieties with black, white and other colours which are not very common (Saanin, 1955).

According to Lin (1950), the Chinese select female breeders 3 to 6 years of age weighing over 2 kg with soft and large belly. Smaller active males with lesser weight are introduced along with the females for breeding.

In the Philippines, in routine carp breeding care is taken to select individuals that are found to be fast growing and hardy.

In India, special care is taken to select healthy gravid females with soft abdomen bulging right up to the region of the vent. Such a female when kept on its belly on the ground will rest on it and the belly will sag. When the fish is held upside down a small crease will be formed between the pectoral and pelvic regions. Further it will not have a median ridge between the pelvic and anal regions, and the vent will be projected very slightly like a smooth papilla with the distal margin gently cleft at the middle. Healthy deep-bodied males with relatively smaller head and soft abdomen and oozing milky white milt are selected .

4.1.2 _Puntius javanicus_

Puntius javanicus popularly known as 'tawes' is a fresh-water river fish but thrives in slightly brackish water also. It spawns in rivers during the rainy season, but also attains sexual maturity in ponds and breeds there under favourable conditions.

4.1.2.1 Breeding methods

In Indonesia, tawes are bred in special spawning ponds, usually with an area varying from 200 to 400 sq m and a depth of 35 to 50 cm. The pond bottom should preferably consist of a mixture of sand and silt, though in some ponds it is covered with fine gravel. The pond is then slowly filled with well-oxygenated water and the breeders that have been conditioned for 3 to 5 days in running water are introduced. In each pond about 30 to 50 pairs of breeders that have been kept segregated are released. Spawning usually occurs at night when a humming noise is produced. In case spawning does not occur, the fish are induced to breed by beating the water with bamboo slats. The fertilized eggs settle at the bottom and are evenly spread there. Flow of water is then stopped. The eggs hatch out within 2 to 3 days and the fry are reared in the spawning pond till they reach a length of 2 to 3 cm.

Saanin (1955) has described two breeding methods, viz, (a)Awipari method (commonly practised in West Java, Central and East Java and in Central Sumatra) and (b) Purbaratu method (practised in Eastern part of West Java). The method described above is similar to the Awipari method. In the Purbaratu method, the spawning pond consists of two compartments. While the first compartment serves as a reservoir and sedimentation tank, the second compartment is the actual spawning pond. A larger number of fish can be bred at a time by this method. Schuster (1952b) has described a third method for breeding tawes which has been developed in East Java. The spawning pond 0.1 - 0.2 ha in area is constructed in such a place that it receives sufficient quantity of rainwater from the catchment area. A small pit (4 m x 4 m) is dug at the bottom of the pond into which breeders are released. After a heavy shower the rainwater from the catchment area enters the pond and the fishes are induced to spawn. This resembles the bundh type of pond in India which will be described in a subsequent chapter. Tawes can be bred at intervals of 3 or 4 months and a breeder can spawn a maximum of five times. The males can be used for breeding about 50 days after every spawning.

In Thailand,breeding of tawes is carried out more or less in the same manner as in Indonesia. In Malaysia, tawes locally named "lampam jawa" was introduced in 1953. The fishes were bred regularly in the fry stations and stocked subsequently in the Perak river and Chendroh lake where it has successfully established itself. The Fisheries Division of the Ministry of Agriculture and Co-operation has undertaken research aimed at improving the technique of fry production and the breeding of a fast growing strain from the imported stock (Soong, 1965).

4.1.2.2 Selection of breeders

The Indonesian fish farmers select female tawes 14 months to 2 years old and about 300 g in weight for breeding. The males should be at least 10 months old. Breeders with large bright silvery scales arranged in regular rows, high body, rounded belly, pointed snout and the genital opening placed nearer to the caudal peduncle are usually selected for breeding.

4.1.3 Osteochilus hasselti

Osteochilus hasselti, popularly called 'nilem' in Indonesia is cultivated in ponds and can be bred in special spawning ponds. The technique has been highly developed in West Java.

4.1.3.1 Breeding methods

Four different methods are employed in different centres for the pond breeding of Nilem.

Galunggung method. As Nilem requires clear, well-oxygenated flowing water for spawning a sedimentation tank is provided in this method in addition to the spawning and hatching ponds. The spawning pond has a gradually sloping bottom and can be drained completely. The spawning ground covered by grass is towards the shallower part of the spawning pond. Clear water from the sedimentation tank flows into the spawning pond which has an outlet provided with gauze leading to the hatching pond. The hatching pond is paved with stones covered with a thin layer of gravel.

The male and female breeders are segregated and conditioned for about a week in ponds having a strong flow of water, after which they are released in the spawning pond. The flow of water is increased after the introduction of breeders and a strong current is maintained to induce spawning. The fertilized eggs are swept into the hatching pond by the current of water where they spread evenly at the bottom. The eggs hatch out by the third day and the larvae are collected within another 4 to 5 days.

Tarogong method. In this method, the spawning pond is constructed in one corner of a brood fish pond which generally has an area of about 1 ha, and is completely drainable. The hatching pond (5 m x 1 m), the bottom of which is covered by a thin layer of gravel, is situated outside the spawning pond. After the release of breeders the outlet is closed and water level increased. Later, water is allowed to flow into the hatching pond, creating a current of water which induces the fish to spawn.

Wanaradja method. This resembles the Tarogang method except that the hatching pond is connected with a large pond into which the fry can be led through a bamboo pipe where they are reared.

Magek method. In this method the spawning pond roughly 60 cm x 30 cm in size and maintaining a depth of 30 cm of water, is fed from another smaller pond situated at a higher level so that water flows into it in a strong current (Hora and Pillay, 1962). The hatching pond is connected with the spawning pond and also to a drain by means of an outlet. The bottom of the hatching pond is covered with a layer of indjuk fibre kept in place by bamboo frames. Spawning takes place in the spawning pond and the eggs are carried to the hatching pond by the current of water.

4.1.3.2 Selection of breeders

One to two year old breeders are usually selected for breeding. One female breeder can be used for breeding every 6 months or sometimes even after 3 months to the maximum of 5 to 8 spawnings. The ratio of male and female introduced for spawning is ordinarily 1:1. Soft and large-bellied females and oozing males are selected for breeding.

4.1.4 Trichogaster pectoralis

Trichogaster pectoralis or 'sepat siam' spawns in ponds and also in rice fields. The male prepares a foam nest in which eggs are laid. The fertilized eggs float to the surface beneath the foam nest, and hatch out in 2 to 3 days. The larvae are guarded by the male.

Although the natural spawning season of sepat siam is from April to October, it is bred almost throughout the year in ponds in Thailand. The fish spawns in ordinary ponds having a rich growth of submerged weeds like Hydrilla verticillata, several times a year. A supply of fresh oxygenated water is conducive to its spawning and conditioning of breeders before introduction into the pond has been observed to be beneficial.

Spawning ponds for sepat siam in Indonesia are rather deep and provided with floating and emergent aquatic weeds like Pistia stratiotes, Ipomoea repens, Limnanthemum indicum, etc. Once the pond is filled with water, no additional inflow is maintained. The dry season is considered best for breeding as rains usually destroy the bubble nest and affect the eggs.

Sepat siam reaches maturity at the age of 4 months. Specimens more than 6 months old (100 g) are generally selected for breeding. Ratio of male to female is 1:1.

4.1.5 Osphronemus goramy

Gourami breeds almost throughout the year and the provision of suitable aquatic plants or other materials for the construction of nests, is all that is normally required to facilitate its breeding.

Hofstede and Ardiwinata (1952) and Saanin (1955) have given accounts of the various methods practised by the Indonesians. Special spawning ponds varying from 25 sq m to 100 sq m in size and 75-100 cm in depth are used as spawning ponds. The indjuk or arenga fibres, dried grass or similar materials are thrown into the pond for nest making. Sometimes conical bamboo baskets are placed along the embankments about 20 cm below the water surface. Spawners are introduced at the rate of one set consisting of 1 male and 1 to 3 females per 25 to 30 sq m area of the pond. The female builds a spherical nest with a small opening at the lower end, out of arenga fibres and dried grass arranging them in the basket. The fertilized eggs are deposited in the nest. A fishy smell and the presence of an oily substance on the water surface are considered as signs that spawning has taken place.

Soon after spawning the nest is taken out and the eggs are transferred to earthenware jars of about 10 litres capacity. The 3,000 to 4,000 eggs laid in a nest are distributed to 3 to 4 jars, which are placed in shade or kept floating in the pond. The water is changed at least twice a day. The eggs are hatched in 5-7 days. After the tenth day food in the form of very fine rice bran is provided and at the age of 3 weeks the fry are transferred into a fry pond. A modification of this method is practised by the fish farmers of Singaparna in West Java where a small pond with a continuous flow of water is used for hatching.

In a few other districts of West Java gourami breeding and nilem rearing are carried out in a common pond (700 sq m in size). In some cases tawes is also introduced in the same pond. Aquatic plants like Hydrilla, branching stems of the common bamboo and indjuk fibre are provided to facilitate nest building. The number of breeders introduced is at the rate of one female per 100-150 sq m of water area. Brood fish are specially fed on soft leaves of plants like Colocasia, Carica, Ipomoea and Manihot or on rice bran. In about 7 to 10 days the females build the nests and spawning occurs within another three days.

In India, no special pond is provided for breeding. In the same pond where gourami is cultured, plants such as Typha are grown in the marginal areas where the nests are built. In some cases additional nest building material may be provided. The fish breeds almost all the year round with the peak period from September to November in Madras and April to May in Bombay (Kulkarni, 1946). Nests of different sizes are constructed and the fecundity also vary from place to place (Bhimachar et al., 1944; Kulkarni, 1946).

In Ceylon (Indrasena and de Silva, 1965), and in a few other countries in the Indo-Pacific region no special spawning pond is used and the breeding methods employed are more or less similar to that in India.

In the Philippines, breeders are introduced into larger ponds with a depth of 1.5 m or more and having good marginal growth of aquatic vegetation.

Gourami is reported to attain maturity at the age of 1½ to 2 years. The fish farmers prefer 3-8 years old gourami for breeding purposes. The fecundity is believed to increase with age and varies from 500 to 4,000 eggs. Selected female breeders have plain body colour, reddish fin rays, rounded and relatively long belly and regularly arranged scales. The males are distinguished by the presence of a hump on the snout.

4.1.6 Helostoma temmincki

In Indonesia, the kissing gourami is bred in specialized spawning ponds and also in freshly harvested rice fields. The size of the spawning pond varies from 30 sq m to as large as 700 sq m. The spawning ponds are drained out completely and the bottom is dried up and then filled with water to a depth of 50-60 cm. Paddy straw or some floating aquatic weeds are spread on the surface of water which provide shade to the eggs and also give protection to the larvae against rain and sun. In small ponds the whole surface is covered but in bigger ponds only the marginal areas are covered.

Before introduction to the spawning pond the breeders are kept in segregation ponds for 3 to 4 days. One pair of brood fish is introduced per 30 to 50 m^2 of the surface area. Spawning occurs within 18 hours after introduction and the eggs hatch out in two days. The larvae float on the surface of the water for 3 to 4 days, after which they move slowly into deeper waters. After spawning the breeders are transferred to the stocking ponds.

In rice fields the breeding of kissing gourami is carried out immediately after the harvest of the paddy. The bunds are raised and strengthened so as to maintain a water depth of 30-40 cm. The breeding technique is more or less the same as practised in the spawning ponds. Stocking rate of brood fish is also similar to that for spawning ponds. After spawning the straw is cut and spread on the surface of water. The paddy straw gives shade and shelter to the eggs and larvae.

One to 1½ years old fish are usually selected for breeding. The weight of the female fish is approximately 150 g. Each brood fish can be bred 4 to 5 times at intervals of six months.

4.1.7 Tilapia mossambica

Tilapia mossambica is an euryhaline mouth breeder and breeds in fresh water, brackish water and even in the sea. The fish breeds almost throughout the year and although the fecundity is not very high, the fish quickly establishes itself and a high population is produced because of the protection afforded by the mother (Vaas and Hofstede, 1952).

The fish attains maturity and starts breeding when 2-3 months old. In Indonesia, Vaas and Hofstede (1952) observed tilapia to mature when 9-10 cm long but Panikkar and Tampi (1954) report that "Fish of 55-60 mm size have been observed to carry embryos in their mouth". A female breeds even 7 to 8 times in a year. No special spawning technique is followed as the fish readily breeds in all waters. On the contrary as the fish propagates quickly, proper control of its reproduction is necessary for manipulation of its population in the pond. The males make circular depressions of 30-35 cm in diameter and about 6 cm depth at the bottom of the pond where the eggs are laid by the females. The pond bottom therefore should not be very hard or rocky. The females pick up the eggs in the mouth immediately after they are laid and fertilized. Hofstede (1948) described a method practised in Indonesia where separate spawning ponds and fry ponds are maintained. The brood fish are stocked in the spawning pond and when the eggs have hatched the female breeders are disturbed and then they spit out the larvae. The water from the spawning pond along with the fry is drained into the fry pond which is situated at a lower level. This operation is repeated every fortnight and the advanced fry are collected occasionally from the fry pond.

No special effort is made for the selection of breeders. Mature males can be distinguished by the darker colour of the body and red margins of the fins. A marked difference in the genitalia also exists. The male has two orifices whereas the female has three. Besides, the female can also be identified by the distended brood pouch in the mouth (Vaas and Hofstede, 1952).

The main problem in tilapia culture is to find out means to prevent or check reproduction of the species for proper stock manipulation and raising fish of marketable size. Mono-sex culture(Huet, 1960; Kong, 1963) where the males only are raised, gives very encouraging results, but the accidental entry of females which often takes places creates difficulties. Sexing requires skill, takes time and is a tedious process and so in large-scale operations there is every likelihood of making one or two mistakes in selection which is sufficient to defeat its very purpose. Mono-sex culture is therefore not very popular in the Indo-Pacific region and the culture of hybrids appears to be the solution to the problem.

4.1.8 Etroplus suratensis

Etroplus suratensis or the pearl-spot is primarily a brackish-water fish, indigenous to India and Ceylon (Job et al., 1947; Alikunhi et al., 1952). It thrives fairly well in fresh water and is cultivated both in the brackish- as well as in fresh-water ponds. The fish breeds almost throughout the year in fresh- and brackish-water ponds, the peak period being December to February.

The pearl-spot attains maturity at the end of the first year when it is 15 to 18 cm long. No special spawning ponds are maintained. As the eggs are attached by the female to any submerged object, in the same rearing pond some hard objects like wooden planks, slate slabs, stones, bricks, bamboo poles etc. are introduced. In South India the broad stalks of coconut leaves are also provided for the purpose. The female usually attaches eggs one by one in rows to the lower surface of the submerged object. In case of intensive cultivation of the species the breeders are selected and introduced in special spawning ponds or cement cisterns provided with objects for attachment of eggs for breeding. The spawn are transferred to nurseries where they are reared to fingerling stage.

4.1.9 Miscellaneous species

In addition to the important pond breeding cultivated species already described above, mention may be made of the following species which are also cultured in some of the countries of the Indo-Pacific region.

4.1.9.1 *Puntius orphoides*

Although *Puntius orphoides* or 'mata merah' has a wide distribution over Indonesia, Malaysia, Thailand and Cambodia, it is only in Indonesia that the species is cultured. The breeding technique has been developed in recent years. It can be bred throughout the year. Construction and preparation of spawning ponds for this species are the same as those for tawes, excepting that the materials for attachment of eggs such as *indjuk* fibres, grass, straw etc. are provided. Well oxygenated water is supplied to the spawning pond and about eight months old breeders weighing roughly 60 to 85 g are introduced after conditioning for at least two days. The fish are also bred in rice fields. For one pair of brood fish about 30 m^2 of pond area is required.

4.1.9.2 *Carassius carassius*

Carassius carassius or the Crucian carp is bred in special spawning ponds by the Japanese fish farmers. Male brood fish should be more than five years old, 30 cm to 60 cm in length and 2 to 4 kg in weight. The female should be more than three years old, 25 to 50 cm in length and 0.8 to 3 kg in weight (Hora and Pillay, 1962). For every female three males are introduced in the spawning pond. Water weeds like *Myriophyllum* are provided for attachment of eggs.

4.1.9.3 *Ophicephalus marulius* and *Ophicephalus striatus*

The murrels *Ophicephalus marulius* and *O. striatus* breed in ordinary ponds usually immediately preceding the monsoon months in India. *O. striatus* breeds in Indonesia from January to May and in Ceylon before and after the rainy season. Parental care is practised by these fishes. The parents build nests which are circular areas made amidst marginal weeds. Fertilized eggs float on the water surface in the nest. Both the parents guard the nest and protect the young ones till they are able to fend for themselves. (Chacko and Kuriyan, 1947; Alikunhi, 1953). No special breeding techniques are adopted for these species by farmers.

4.1.9.4 *Clarias batrachus*, *Heteropneustes fossilis* and *Anabas testudineus*

This group of fishes, called "live fishes" because they possess accessory respiratory organs by means of which they are able to take oxygen directly from the atmosphere, mature in the first year and breed in ponds during the monsoon months. Usually after a heavy shower when the adjoining area of ponds gets inundated, these live fishes migrate to those areas and breed there. The eggs of *Anabas* or the climbing perch are small, transparent and float to the surface of water while those of the two catfishes are coloured, sticky and are attached to grasses.

4.2 Breeding in bundh-type ponds

The breeding requirements of the cultivated species of Indian carps *Catla catla* (catla), *Labeo rohita* (rohu), *L. calbasu* (calbasu), *Cirrhina mrigala* (mrigal) etc. and Chinese carps (*Ctenopharyngodon idella* (grass carp), *Hypophthalmichthys molitrix* (silver carp), *Aristichthys nobilis* (big head), *Mylopharyngodon piceus* (black carp), etc. are more complex than the pond breeding fishes. They do not breed in ordinary ponds. But the Indian carps have been known to breed in special type of perennial and seasonal ponds or impoundments locally known as "bundhs" in some parts of West Bengal and Bihar in India and in Chittagong district of East Bengal, (Pakistan) (Das, 1917; Mazumdar 1940; Mookerjee *et al.*, 1944; Hora, 1945).

The main characteristics of the breeding bundhs are that they receive considerable quantities of rain water with washings after a heavy shower, from the extensive catchment areas and they have large shallow marginal areas which serve as spawning grounds for the fish.

A brief description of the different types of carp breeding bundhs and the existing practice of breeding and hatching of these fishes mainly after Mookerjee *et al.*, (1944) are given below.

4.2.1 Description of bundhs

The bundhs are ordinarily of two categories, viz; perennial bundhs commonly known as 'wet bundhs' and seasonal ones known as 'dry bundhs'.

Wet bundhs: A typical Midnapur type of wet bundh is a perennial pond situated in the slope of a vast catchment area of undulating terrain with proper embankments and having inlet towards the upland and an outlet on the opposite side. It has an extensive shallow area which dries up during summer but the actual pond retains water throughout the year where an adequate stock of mature carps is maintained. After a heavy monsoon shower fresh rainwater with washings from the upland area rushes into the bundh through the inlet in the form of streamlets which are locally known as "dhals". Thus the major portion of the bundh gets submerged and during heavy floods it may even overflow, the excess water being drained through the outlet known as 'bulan'. The shallow areas of the bundhs are called "moans" which are the main spawning grounds of carps. These 'moans' may be situated either near the outlet or in some cases adjacent to the inlet. The outlet is protected by a bamboo fencing known as "chhera". The flow of water through the outlet can be controlled by plugging the 'chhera' with straw and mud (Mookerjee,1945a).

Dry bundhs: A dry bundh is a seasonal pond and differs from a wet bundh in usually being shallower and much smaller in size than a wet bundh. With the first shower when water accumulates in the shallow depression of the dry bundh, selected mature carps from nearby ponds are released in the bundh. Usually with the next heavy shower when the dry bundh gets flooded, fishes get stimulated and breed in the pond.

There are, however, modifications and improvements over the typical wet and dry bundhs described above and also variations exist in different regions where bundh breeding of carp is practised.

4.2.2 Spawning of carps in bundhs

Spawning in bundhs usually occurs after continuous heavy showers when large quantities of rain water rush into the bundh and the water level increases considerably. At first the smaller fishes get stimulated and migrate to the shallow areas of the bundh itself or to the inundated shallow spawning ground. Later on the bigger fishes start spawning in the same area.

4.2.2.1 Spawning behaviour and sex-play

Spawning behaviour of carps in bundhs is very peculiar and considerable activities and sex-play are observed at the time of spawning. During sex-play the spawners rush at a high speed, males chasing females with violent splashing of waters. Usually a female is chased by more than one male and finally a male gets at the female and mating starts. During the act, the female is held in a sort of grip by the male and the male is seen just at the surface of water bending over the female while the latter gives constant jerks with its tail and eggs can be seen coming out in a stream. The male also quivers at the time of coiling probably ejecting milt over the released eggs. Sometimes the pairs turn upside down in the course of mating. The mating lasts for a few seconds and is repeated till the female is fully spent. After the mating is over, the breeders become quiet for some time and then slowly swim back to the deeper waters of the main bundh (Dubey and Tuli, 1961; Alikunhi *et al.*, 1964b). The fertilized eggs sink to the bottom and are not visible in West Bengal bundhs where the bundh water is generally very turbid but in some of the Madhya Pradesh bundhs the eggs laid are clearly visible in the spawning area.

4.2.2.2 Collection of eggs and hatching

Collection of eggs in Midnapur bundhs are usually made 9 to 12 hours after the commencement of spawning. The proper time for egg collection is when the embryo shows twitching movements. Very often when spawning is continued for a long period, there is every possibility of some eggs being hatched out in the bundh itself or eggs being prematurely collected. The eggs are transported to a battery of rectangular hatching pits which are fed by drains from the bundh or any other nearby pond. Palm leaves are spread over the pits to give shade and protection to the hatchlings. The eggs hatch out 15 to 20 hours after fertilization and the fry are sold to the public from the fourth day onwards. In Madhya Pradesh the general practice is to collect the eggs from the breeding bundhs or reservoir and hatch them in hatching *hapa* fixed in the bundh itself (Alikunhi *et al.*, 1964b) or sometimes the eggs are not collected and are allowed to hatch in the bundh (Dubey and Tuli, 1961).

4.2.3 Spawning conditions and factors responsible for bundh spawning

Various views have been advanced by workers (Hora *et al.*, 1945) regarding the factors responsible for the spawning of carps. Khan (1945) after a detailed study of the spawning behaviour of carps at the Chhenawan fish farm, Punjab, concluded that probable factors are the rains accompanied by floods which stimulate the fishes to migrate to the spawning ground but the fish spawns only when the temperature of water is optimum that is, between 24°C and 30.5°C. According to him, the oxygen content of water and other physico-chemical constituents of the flood water as such, were not responsible for spawning. Husain (1945) stressed monsoon floods as the first requisite for spawning, which was supplemented by temperature and other factors. Mookerjee (1945 *b*), on the other hand, emphasised mainly the high dissolved oxygen content of water present in the fresh rain water as essential for the spawning; rain, flood, shallowness of the spawning ground, etc., according to him are only secondary factors. He has also stated that mere replacement of old water of a pond with fresh rain water would induce spawning of carps (Mookerjee, 1945 *a*).

Das and Das Gupta (1945) observed that although an increased pH value and high oxygen content in water play an important role in the spawning of carps, they have no independent significance. According to them rise of temperature to a certain degree is essential without which "no spawning of carps is possible". Some have attributed spawning to currents that are produced in many bundhs after a heavy shower, but Das (1917) and a few others have found that breeding occurred when there was no current either flowing into the 'bundh' or out of it. It has been observed that breeding in the bundhs of Midnapur is probably stimulated by the inflow of large quantities of silt-laden water from the catchment area after heavy rains resulting in an abrupt rise of water level in the bundh and changing suddenly the physico-chemical condition of water. Study of the physico-chemical conditions of water of a number of bundhs showed that a highly turbid (about 2000 ppm) water with a distinct reddish colour, a low pH (6.2), a low total alkalinity (trace to less than 2 ppm) and temperature 27 to 29°C were the conditions at the time of spawning. A primary factor of importance noted in Rangamati bundh where observations were continued for about a month prior to breeding, was the abrupt increase in specific conductivity of water during breeding. Saha et al. (1957), after studying a few dry and wet bundhs of the Bankura District of West Bengal, concluded that almost neutral water with low alkalinity was favourable for the spawning of carps. Dubey and Tuli (1961) made observations on the spawning of carps in several reservoirs and minor irrigation tanks in Madhya Pradesh and found that the spawning occurred only after rains in various depths of water with or without any flow, in hard as well as in soft and sandy soil, with a pH ranging from 7.2 to 8.2 and temperature between 26 and 33°C. Alikunhi et al. (1964b) observed spawning in both wet and dry bundhs in stagnant water in Madhya Pradesh. In dry bundhs having recent accumulation of rain water the pH and total alkalinity were lower than those in wet bundhs in which, though there had been appreciable dilution, water was neither turbid nor so fresh. Successful spawning was observed both in cool weather after local rains and also in warm dry weather.

From the views expressed above by various workers, although it is very difficult to come to a definite conclusion as to the most important factor or factors influencing spawning of carps in bundhs, the consensus seems to be that fresh rain water and flooded condition in a tank are the primary factors providing the stimulus to spawning and the sex-play finally helps in releasing the pituitary hormones and ovulation in carps. The presence of "repressive factor" (Swingle, 1956) might also be responsible for the carps becoming refractory in confined waters. The inrush of flood water in the bundhs probably dilutes the repressive element sufficiently and thus spawning is precipitated.

Chinese carps which were believed to breed only in their home waters in China were first reported to have bred in rivers of Japan (Kuronuma, 1954), and more recently in the Ah Kung Tian reservoir in Taiwan (Tang, 1960).

4.3 Induced breeding by hormone injections

In the foregoing Section (4.2), a detailed account of the breeding of Indian carps in special type of ponds called 'bundhs' has been given. The technique, however, has its limitations and cannot be universally practised since the 'bundhs' can be constructed only in areas where the topography is one of undulating terrain. Moreover, the construction and maintenance of a perennial or seasonal bundh is very expensive and beyond the means of average fish farmers. Lastly, since bundh breeding is dependable to a great extent on the climatic and environmental conditions, success is unpredictable and poor results are very often reported due to failure of rains. Hence, the need to develop better and more dependable source of fish seed has been immensely felt. The recent success in breeding the above mentioned carps by administration of fish pituitary hormone has opened new possibilities in solving the pressing problems of dearth of seed of these economic food fishes.

4.3.1 History of pituitary treatment in fish culture

Before going into the details of the technique followed in inducing breeding of carps, it is desirable to make a passing reference to the history of pituitary treatment in pisciculture. Atz and Pickford (1959) has given an account of the use of pituitary hormone in fish culture in different countries of the world.

Brazil was the first country ever to develop a technique of breeding fish by injection of fish pituitary hormones. Following the work of Houssay (1930) of Argentina, von Ihering and others in Brazil started experimenting with various hormone injections and finally succeeded in breeding Brazilian fishes by the administration of fish pituitary hormones in the year 1934 and obtained normal young ones (von Ihering and Wright, 1935; von Ihering, 1937). Since then the Brazilian fish culturists are using the technique to obtain seed of the indigenous fishes as part of their regular piscicultural program. Fontenele (1955) has given a detailed account of the procedure followed by the Servico de Piscicultura in Brazil.

The Russians were the next to introduce hormone treatment in fish culture. They have made extensive use of this technique for solving the problems caused by the construction of dams in many rivers in which sturgeons and other important migratory species breed. With the first success in breeding sturgeons in 1937 by Gerbilskii (1938), the pituitary treatment method is being successfully applied in fish culture for obtaining all eggs of sturgeon in the sturgeon farms situated on the lower Volga, Ural, Kura, Kuban and other rivers (Gerbilskii, 1965).

In the United States, the technique is mainly employed in the production of bait minnows (Ball and Bacon, 1954) and for the culture of channel catfish, Ictalurus punctatus, a commercial as well as sport fish (Clemens and Sneed, 1957; Riggs, 1958). Attempts have also been made to induce spawning in Pacific salmon (Oncorhynchus spp.) which are prevented from reaching their spawning grounds by the construction of dams in the rivers but success has not been achieved so far (Burrows et al., 1952; Palmer et al., 1954).

In India, the first success in inducing breeding of major carps by pituitary injection was achieved in 1957 (Chaudhuri and Alikunhi, 1957) and since then the technique has been used as a regular part of fish cultural procedure. More recently, a similar technique has been successfully employed in the breeding of the Chinese carps also (Alikunhi et al., 1963b; 1965).

In Taiwan, fish culture has been rejuvenated by the success obtained recently in spawning the Chinese carps by pituitary treatment (Tang et al., 1963) and promising development towards commercial production of fish has been initiated (Tang, 1965; Lin, 1965).

Fukushima (1965) has reported successful spawning of Chinese carps by hormone injections, throughout the mainland of China and a production of 1200 million fry was reported to have been achieved during 1962.

4.3.2 Breeding of Indian carps

The Indian major and minor carps such as Catla catla, Labeo rohita, L. calbasu, L. gonius, L. fimbriatus, L. bata, L. boga, Cirrhina mrigala, C. reba etc. are the important pond fishes successfully bred in India by injection of fish pituitary hormones. The pituitary glands for injection are collected just prior to or at the beginning of the breeding season from fully mature gravid fish. Glands from immature or spent fish do not give satisfactory results. However, glands of induced bred fish, collected immediately after spawning have been observed to be potent and are effectively used. Ordinarily glands from the same species as the recipient fish are used, but glands from other closely related species as also from fishes belonging to different families have given positive results. Care is taken to collect glands from fishes soon after capture, although those procured from fishes preserved in ice are also found to be potent.

Preservation of glands is made in absolute alcohol and preferably stored under refrigeration in air-tight glass stoppered phials. The glands after proper preservation are weighed individually or collectively in an electric balance. The weight is noted exactly after two minutes calculated from the time of removal of the gland from absolute alcohol. The weighed glands are again transferred to phials in absolute alcohol and stored till the time of injection, when the required quantity of glands as calculated from the weights of the breeders to be injected are taken out, allowed to dry for a few seconds and then macerated in a tissue homogenizer with a little distilled water or 0.3 percent common salt solution. The homogenized glands are next diluted with the same liquid, the rate of dilution being 0.2 ml per kg body weight of the breeders. The gland suspension is next centrifuged and the supernatant fluid is taken in a hypodermic syringe for injection. To avoid preparation of the extract every time just prior to injection, a simplified method has been successfully tried by preserving the extract in glycerine and then storing either in an air-tight phial or preferably ampuled and stored for future use (Ibrahim and Chaudhuri, 1965).

Determination of proper dosage depends mainly on the proper stage of sexual maturity of the breeders. By careful selection of breeders and injecting an adequate weight of pituitary gland per kg body weight of the breeders 60-100 percent success can be obtained provided the water temperature is optimum. Depending on the condition of the female breeder, a single injection of 5 to 10 mg of homoplastic pituitary gland per kg of its body weight may give successful spawning. In usual practice however, the female alone is given a preliminary dose of 2 to 3 mg per kg body weight and kept segregated. After 6 hours a second dose of 5 to 8 mg per kg body weight is administered to the female and a first dose of 2 to 3 mg per kg body weight is given to the males, after which the males and female are put together for breeding. Intramuscular injections are given on the caudal peduncle or near the shoulder region using a 2 ml hypodermic syringe graduated to 0.1 ml division. B.D. needle No. 22 is used for fish weighing 1.0 to 3.0 kg and No.19 is used for larger ones. For smaller fishes needle No.24 can be used.

The major carp breeders are raised in ponds. A few months prior to the breeding season, 2 to 4 years old adults are collected and stocked in brood fish ponds for breeding purposes. Proper care of the breeders is taken and with the advent of monsoon when fishes become fully mature and the temperature of water goes down, breeding operations are started.A male breeder can be easily distinguished by the roughness of the dorsal surface of the pectoral fin in contrast to that of a female which is smooth to touch (Chaudhuri, 1959a). Fully ripe males which freely ooze milt when gently pressed on the abdomen are selected. Selection of a female breeder in prime condition is rather difficult. Ordinarily a female having a soft,bulging rounded abdomen and with swollen, reddish vent is selected for breeding. Female breeders are also cathetered before selection so as to find out the condition of eggs. Healthy breeders weighing 1.5 to 5.0 kg are preferable, as they are easy to handle.

Selected breeders are collected in hand nets and weighed. The quantity of pituitary glands required is next calculated from the weights of breeders and the suspension prepared. The breeder wrapped inside the hand net is then placed on a soft cushion and injected intramuscularly. One set of breeders consisting usually of two males and one female is then introduced into one breeding _hapa_1/. The breeding _hapa_ are fixed by bamboo poles in the marginal waters of ponds.

Spawning ordinarily takes place within 3 to 6 hours after the release of the injected breeders. In case no spawning occurs, a third injection with a slightly higher dose is given 10 to 12 hours after the second injection to the females. No vigorous sex-play is observed as in nature but chasing of the female by the male with a little splashing of water is usually noticed at the time of spawning. The eggs are non-adhesive, demersal and swell up considerably after fertilization to the size of a pea. Approximately 8 to 10 hours after fertilization, the embryo starts twitching movement. By that time the eggs get properly water hardened and are removed from the breeding _hapa_. Breeders are then collected and usually sacrificed for collecting glands.

A quantitative assessment of the eggs are made from the total volume and percentage of developing eggs are estimated from samples. The eggs are next distributed uniformly to a number of hatching _hapa_2/.

1/ A breeding _hapa_ is a rectangular mosquito net container (or of plastic net) with a cover which opens on one side where it can be securely tied after introduction of the breeders. Size of _hapa_ varies from 1.8 m x 0.9 m x 0.9 m to 3.6 m x 1.8 m x 0.9 m according to the size of breeders.

2/ A hatching _hapa_ consists of an outer _hapa_ made of thick-meshed cloth or nylon stitched in the shape of a rectangular trough without any cover (Size - 1.8 m x 0.9 m x 0.9 m) and inner _hapa_ of similar shape and made of round-meshed mosquito net (size - 1.75 m x 0.75 m x 0.45 m.) fitted inside the outer one.

The hatching *hapa* are tied to bamboo poles in marginal waters of ordinary ponds. About 0.075 to 0.1 million eggs are uniformly spread on the stretched bottom of the inner *hapa*. The eggs hatch out in 15 to 18 hours after fertilization at a temperature of 27 to 31°C. After hatching, the hatchlings escape to the outer *hapa* through the meshes of the inner one. Egg cases and bad eggs are left in the inner *hapa* which is removed when all the eggs have hatched out. The hatchlings are left undisturbed in the outer *hapa* till the third day after hatching. By that time yolk gets almost absorbed and the young fry start feeding. They are collected and stocked in nursery ponds.

The hydrological and climatic conditions studied (Chaudhuri, 1960) during induced spawning of carps indicated that - (i) spawning occurs both in clear as well as in turbid waters and during day or night; (ii) injected fish breed successfully when the water temperature ranges between 24 and 31°C, the optimum being around 27°C. Even if the fish spawn at a higher temperature, the percentage of fertilization and hatching is relatively low; (iii) fish breed at a fairly wide range of pH and dissolved oxygen contents of water; (iv) cool, rainy days give better results than hot, sultry days; and (v) rain and fresh rain water are conducive to successful spawning.

The technique of breeding of Indian carps as described above is more or less followed throughout India with slight modifications suited for the particular environment. In several places where the water temperature in ponds is above the optimum the injected carps are introduced in breeding *hapa* fixed in flowing waters in rivers. The temperature of river water is at least 2°C below the pond temperature. At the Central Inland Fisheries Research Sub-station, Cuttack, preliminary attempts made to breed carps in the air-conditioned laboratory at controlled temperature (27 to 28°C) gave encouraging results. One set of rohu and one set of calbasu were bred successfully in 1962 and subsequently Alikunhi *et al*. (1964a) conducted elaborate experiments and obtained 0.8 million spawn.

4.3.2.2 Breeding of Chinese carps

In India: The Chinese silver and grass carps were first introduced into India when experimental consignments were brought to Cuttack during September and December, 1959, from Tokyo and Hong Kong respectively. Both the species attained sexual maturity at the Central Inland Fisheries Research Sub-station ponds at Cuttack, when about two years old (Alikunhi and Sukumaran, 1964). During July 1962, when the fish were just three years old, both the species were successfully induced to breed in ponds by injection of fish pituitary hormones. An injected bighead (*Aristichthys nobilis*) also ovulated by hormone injections (Alikunhi *et al*., 1963a; 1963b). Mature males of these Chinese carps are easily distinguished by the processes and ridges on the pectoral fin rays (Tang, 1954). The techniques of breeding adopted were essentially the same as those followed in the case of Indian carps. Success was achieved with homoplastic as well as heteroplastic injections of pituitary glands collected from Indian carps. A total of 9 mg per kg body weight injected in two doses to females gave successful results. The female usually starts oozing 6 to 8 hours after injection. While in Indian carps natural spawning occurs after injections, the Chinese carps generally have to be stripped and the ova artificially fertilized. Chaudhuri *et al*. (1964), however, has observed natural spawning in breeding *hapa* of injected grass carp and subsequently also of silver carp. Alikunhi *et al*. (1965) found the progeny of induced-bred silver carp attaining maturity in the first year itself. The yearlings could be bred and young ones obtained, but in a large number of instances the hatchlings did not survive. In these experiments too, spawning occurred 4 to 8 hours after the second injection to the female but the eggs laid in the breeding *hapa* were not fertilized and artifical fertilization method had to be adopted. In grass carp yearlings, however, only the males were ripe and oozing. Two year old grass carp have been successfully bred (Chaudhuri *et al*., 1966).

In Taiwan: It was during 1963 fish breeding season that first success was reported in inducing spawning of the Chinese bighead, silver and grass carps in Taiwan (Tang *et al*., 1963). The method followed is briefly described below.

Breeders were collected from a reservoir and released before injection in holding tanks with continuous circulation of water. Carp pituitary glands preserved in absolute alcohol were extracted in physiological solution and injected intramuscularly in mature spawners. Females with dilated genital papilla and flaccid abdomen and males with oozing milt were selected for breeding. Successful spawning was obtained in a few which ovulated in 6 to 18 hours after receiving a single injection of one whole gland collected from a carp of comparable size or after receiving a second or third injection of the same dosage. Many did not respond even after repeated injections. The males received a lesser dose of 0.5 to 1.0 pituitary gland. Artificial fertilization of eggs with sperm by hand stripping was followed in all the successful experiments with the single exception of one bighead which was found to ovulate spontaneously in a pond 18 hours after receiving a single injection. The dry method of artificial fertilization was adopted.

About 33 percent success was achieved. The hatching rate in a solitary case was as high as 95 percent but in the majority of cases only about 20 percent or less hatching was observed. The reason for this was mainly attributed to overdose of hormone injected. Lowering of the temperature was believed to be one of the most important environmental factors conducive to induced spawning.

Within a year of the initial success improvements were effected in the breeding and hatching techniques employed for inducing spawning of the Chinese carps and commercial production of their fry was started in a large number of hatcheries (Tang, 1965).

Experiments with fish pituitary combined with chorionic gonadotrophin gave more effective results than administering fish pituitary alone. With this improved method the percentage of success was raised from 33 to 78, thereby achieving an increase of 45 percent success. A number of brands of gonadotrophin were tried, of which Puberogen (contains 250 IU/CC of CG), Gonagen and Synahorin (both contain CG mixed with a little of mammalian pituitary extract) gave encouraging results.

A circular basin with a steady stream of circulating water, which eventually flows out through an opening in the centre (Tang, 1965), was found to be very efficient for hatching.

Lin (1964) as cited by Tang (1965), succeeded in spawning the mud carp, Cirrhina molitorella and the technique followed was almost identical to that of other Chinese carps. He succeeded by injecting glands from the skipjack tuna. Positive results were also obtained by injecting 500 rabbit units of cattle anterior lobe extract combined with fresh toad pituitaries. In all cases of breeding of these Chinese carps, artificial fertilization of hand-stripped eggs was adopted.

Liu (1964) has succeeded in breeding silver carp as early as two months before the normal breeding season. This prolongs the growing season of fish and is a definite advantage to the fish farmers.

In Malaysia: Attempts in inducing the breeding of grass carp by hormone treatment were made in Malaysia but did not meet with much success. Hickling (Personal communication) obtained ovulation in grass carp a number of times by injection of pituitary hormones at the Tropical Fish Culture Research Institute, Malacca, but the eggs could not be fertilized. Artificial fertilization of eggs was tried by him by both the wet and dry methods but no positive results were obtained. He is of opinion that probably the absence of a definite seasonal change of daylight and temperature at Malacca is responsible for the improper maturation of gonads and it is likely that the final meiotic division in the ovum does not take place.

In Japan: Natural propagation of Chinese carps have been observed in recent years and all the species are reported to have established in the Tone river system in Japan. Japanese workers have also succeeded in obtaining large numbers of these species by hatching eggs collected from these rivers (Kuronuma, 1958; Inaba et al., 1958; Suzuki et al., 1958; Suzuki and Takahashi, 1961).

Kawamoto (1950) tried to obtain spawning in grass carp in Japan by feeding the fish regularly with sex hormones mixed with the regular diet. The fish did not spawn, but the application of sex hormones definitely hastened the development of gonads. Injections of hormones has also been tried on Chinese carps and on several other marine and fresh-water fishes. Although no published accounts of these have come to the knowledge of the author, it is understood that the treatment with synahorin in combination with fish pituitary hormones has been tried with success by a few fish farmers.

In China: There is hardly any detailed information or published account available on the induced breeding work carried out in the mainland of China. Isaev (1958) has published an account of the fish breeding in the Chinese People's Republic (not consulted by the author). Recently some information on this subject has been gathered by Fukushima (1965) who reports that all important Chinese carps are bred by hormone injection all over the mainland of China and that fish seed is produced on a large scale by this method. Chorionic gonadotrophin is used to obtain eggs from black carp and big head.

4.3.2.3 Breeding of catfish

Majority of the cultivated species of catfishes breed in ponds. Induced breeding by pituitary treatment could be suitably tried in a few species which do not breed in ponds or for hastening pond breeding.

The large-sized catfish Wallago attu which is common in ponds and in larger impoundments in India and Pakistan, breeds in rivers. This fish has been reported to spawn in bundhs, but so far no attempt has been made to breed the species by hormone injection. The smaller species Ompok bimaculatus (Bloch) which is primarily a riverine fish and is cultivated in ponds, has been induced to breed in cisterns by the injection of 0.4 to 0.5 of a pituitary gland collected from the carps rohu and mrigal (Chaudhuri, 1962).

The Siamese catfishes Pangasius larnaudi Bocourt and P. sutchi Fowler, also cultured in Vietnam, do not breed in ponds and their fry are collected from rivers. Large-scale breeding of these fishes by hormone treatment has not yet succeeded although Tubb (1958) has reported early spawning of P. sutchi accomplished by hormone injection. Two other cultivated species, Clarias macrocephalus Günther and Clarias batrachus readily spawn in ponds and especially the latter species can be bred by the simple replacement of old water by fresh rain water. As such, there is no necessity for hormone treatment in these species for breeding. But in certain cases the pituitary extract is used for getting early spawning of these fishes. Tongsanga et al.(1963) achieved early spawning in mature catfish C. macrocephalus by giving injections of 13 mg, 26 mg and 39 mg of homoplastic pituitary glands per fish 90 to 190 g in weight. The higher doses of 26 mg and 39 mg gave cent percent success.

4.3.2.4 Breeding of mullets

Excepting Liza corsula, which was observed to mature in Pulta Water Works settling tanks near Barrackpore, West Bengal, there is no report of other mullet species attaining full maturity in fresh-water ponds. Pakrasi and Alikunhi (1952) observed breeding of Liza corsula in fresh-water rivers during June and July and states that the fish appears capable of breeding both in brackish- as well as in fresh-water habitats and the breeding season seems to be a prolonged one extending from May to September.

Mugil cephalus is the most important cultivated mullet and has a wide distribution. The only means of obtaining seed of this species is by collecting it from the sea coast, creeks, lagoons and adjoining areas. Besides the difficulties of collection and transport involved, the fry collected are usually a mixture of economic and uneconomic varieties. Attempts were, therefore, made in a few countries to induce them to breed by injection of hormones and raise the fry artificially.

Preliminary attempts were made in India to breed the two important economic species of Chilka lake, namely Mugil cephalus and Liza troschelii, by hormone treatment. (Proc.Indo-Pac. Fish Coun., Section 1:p 40, 70, 1963). Experiments were conducted in lake water and breeders were collected from the sea coast near the lake mouth. Injection of homoplastic pituitary gland extracts (8 mg to 16 mg per kg body weight of breeders) resulted in ovulation of eggs on several occasions in both the species. Both the species could be stripped successfully, but the eggs failed to develop in lake water. When sea water was used, normal development of eggs proceeded on several occasions and on one occasion a Mugil cephalus egg hatched out in 48 hours (22.5 to 23.5°C) after fertilization.

The low salinity of lake water was found to be responsible for failure in getting fertilization of eggs in lake water. It was observed that M. cephalus sperms died immediately when brought in contact with lake water. L. troschelii sperms, however, were active for about a minute. On the contrary, sperms of both the species were found to be active for about ten minutes when mixed with sea water.

The results indicated that it may be possible to get successful spawning of these mullets if experiments were conducted in sea water with facilities for water circulation which appear essential for proper development of eggs and survival of hatchlings.

This work was continued and success has been achieved by the Orissa State Fisheries staff (Personal communication) in 1963 in artificially fertilizing the stripped eggs of injected L. troschelii in sea water and 10,000 spawn were produced which survived for over a week.

Tang and his co-workers in Taiwan carried out experiments during 1963 mullet fishing season and successfully bred Mugil cephalus by hormone injections (Tang, 1964). They were collected from the sea during their spawning migration to the south-western coast of Taiwan. Brood fish were held in special boxes in shallow sea water. The breeding technique followed was identical to that used for breeding Chinese carps. Mullet pituitary extract in combination with Synahorin (a mixture of CG and mammalian pituitary extract) was used. No ovulation occurred when 1.0 to 3.0 pituitaries alone were injected or when the fish received combined extract of less than 2.0 pituitaries plus 40 rabbit units of Synahorin. Positive results were obtained when 2.0 fish pituitaries combined with 40 rabbit units of Synahorin were injected, which is considered to be the threshold dosage for successful spawning. Artificial fertilization of hand-stripped eggs was made following the dry method. The developing eggs were hatched in aquaria with circulation of sea water and also under natural conditions near the sea coast. Hatching took place in 59 to 64 hours at a temperature 20.0 to 24.5°C and in salinities of 24.39 to 35.29 parts per thousand. Most of the larvae died within two days after hatching and none survived beyond four days.

High mortality of brood fish after injection hampered the experiments. The authors believe that the response of these mullets to hormone injections could be greatly improved if the fish were kept in better condition at the time of the experiment.

The preliminary success in India and Taiwan, as mentioned above, will go a long way to developing a dependable technique for the spawning and successful rearing of the larvae and early fry of mullets.

4.3.3 General discussion on hormone treatment in fish

Successful hormone treatment of fish and its use in pisciculture started in Brazil in the early thirties when fish pituitary hormones were first used for inducing spawning in fish. This success appears to have given a fresh stimulus to physiologists to conduct intensive research on the physiology of the pituitary gland and its effect on the reproductive behaviour of fishes. Pickford and Atz (1957) in their book on "The physiology of pituitary gland of fishes" have summarized all available information and discussed various aspects of the physiology of fish pituitary gland and its role in present day fish culture.

Although successful experiments have been conducted and techniques developed in a number of countries to breed fish by hormone injection, bio-assay methods have not been developed in any country other than Russia. Atz (Pickford and Atz, 1957) states "Chemical standardization of fish gonadotrophins is of course a thing of the future, and the Russians are the only ones who have developed a method of biological assay". Although the Russians have found out a "Vy'un Unit" (Kazanski, 1949) for assaying fish gonadotrophin, they have yet to solve the problem of dosage of hormone. Gerbilskii (1965) has given an account of the technique of hormone treatment in fish culture followed in Russia. He states that the effectiveness of pituitary injections depends mainly on the coincidence of the time of treatment with the suitable period of the sexual cycle of fish. The study of fish ovogenesis is of great importance to "ensure effective application of pituitary injections and to forecast precisely enough the moment of mating". Sample of ovocytes are collected from injected sturgeon female every five hours during the period of maturing until the completion of ovulation. By making a thorough study of the complex processes, Deltaf and her collaborators, as cited by Gerbilskii (1965), have been able to recommend the proper time for obtaining eggs from the female. In Brazil, the techniques have not been standardized. In the absence of any accurate unit of measurement, Fontenele (1955) suggested a conventional unit which is the amount of hormone obtained from a whole pituitary gland from a Curimata of well-developed gonads. Recently Clemens and Sneed (1962) attempted evaluation of the activity and relative potency of pituitaries of various species of fish collected during various months of the year and also determination of phylogenetic specificity, if any, in pituitary glands by bio-assay methods. In India, however, although the pituitary hormones were not isolated and chemically standardized, fairly satisfactory results were obtained by precautions taken in selection of proper recipient fish (breeder) as well as the donor fish and also in preservation and storage of glands. The dosage given has been always in mg weight of the pituitary gland per kg body weight of fish (Chaudhuri, 1963). Female breeders are also cathetered and eggs examined before final selection.

In general, pituitary glands from fully mature gravid fish are used in induced fish breeding experiments, which are believed to be the most potent. Gerbilskii (1940) observed relatively low potency of gonadotrophins in the pituitaries of spent fish and the same was observed by de Menezes (1945) in the case of immature fish. But Clemens and Sneed (1962) observe "Activity in relation to size, sex and degree of gonadal development of the donor fish does not appear as important as implied by some previous reports in the literature". As regards relative potency of the male and female pituitary glands, the results of research conducted in Brazil (Fontenele, 1955) and also at the Central Inland Fisheries Research Sub-station, Cuttack, India, have shown that the pituitary glands from male and female fish are equally potent. Ramaswamy and Sundararaj (1957), however, observed that in the catfish Heteropneustes fossilis, the pituitary gland of the male is not so potent as the female during the breeding season. The results obtained by the said authors, however, are not strictly comparable as the relative potency was determined by injection of the whole or part of a pituitary and not according to the weight of gland or by any other bio-assay method. Besides, there is difference in size of the donor catfish as males are usually smaller than the females.

In preserving glands, both acetone drying and preservation with absolute alcohol have been found to be effective and are popular with the fish culturists all over the world. Neto and Rebeiro (1946) prepared fish pituitary extracts in glycerine and found that the solution retained its effectiveness for a year when kept sealed in air-tight vials at room temperature. According to de Menezes et al. (1945), glycerine preserved pituitary extracts are more uniform in potency than those in saline or distilled water. Ibrahim and Chaudhuri (1965) found glycerine method very effective and more convenient. Clemens and Sneed (1962), however, are of the opinion that although glycerine extracts are easier to inject, their preparation is tedious. They also observed that administration of more than 10 percent glycerine has harmful effect on the recipient fish.

Phylogenetic specificity in fish pituitary hormones is a subject of controversy. Creaser and Gorbman (1936) believe that there is a specificity in hormone physiology and a qualitative species variation exists in gonadotrophic hormones. When the variation is sufficiently great between widely separated donor and recipient species, it leads to apparent ineffectiveness of the hormone. This view is also supported to some extent by Hoar (1957) who, while reviewing the work of Witschi (1955) pointed out that the refractoriness of fish to mammalian gonadotrophins is probably due to different biochemical materials operating in groups as widely separated as mammals and fish. According to Pickford and Atz (1957), phylogenetic specificity does not appear to be significant in fish culture. Clemens and Sneed (1962) also observed that the specificity is so slight that it has no practical bearing in fish cultural practices. Chaudhuri (1960) reported successful spawning with heteroplastic pituitaries from fishes of the same family as well as from closely related families. Ramaswami and Sundararaj (1957) succeeded in spawning gravid catfish with homoplastic glands or with glands from genera of the same order but the fish became refractory when injected with pituitaries from fish belonging to different orders. However, the same authors reported successful spawning in the catfish by using frog pituitary hormones. Lin (1964), as cited by Tang (1965), succeeded in breeding the Chinese mud carp by injecting pituitaries from skipjack tuna, belonging to a different order not closely related to the carps.

These and other results achieved by a host of earlier workers experimenting with mammalian pituitary hormones, sex hormones and various sex-steroids as reviewed by Pickford and Atz (1957) and Chaudhuri (1956), demonstrated the relative effectiveness of fish pituitary hormones on the spawning of fish, over those of mammalian origin. The fish pituitary hormone was, therefore, used in all the countries for spawning fish as part of regular fish culture work.

Recent findings, however, show that the mammalian pituitary hormones in combination with the threshold dose of fish pituitary glands are able to precipitate spawning in fish (Ramaswamy and Lakshman 1959; Tang, 1965). But out of all hormones of mammalian origin, the chorionic gonadotrophin has been found to be the most effective on fish. Hoar (1957) states "pregnancy urine and chorionic gonadotrophins frequently give positive results but it is difficult to say which of the many factors present on these materials is active". According to Burrows (1949), the chorionic gonadotrophins (CG) behave primarily as a luteinizing hormone (LH) and since LH is believed to be responsible for the growth and maturation of gonads in fish (Kirshenblat, 1956), the effectiveness of CG on fish can probably be explained. Sneed and Clemens as cited by Riggs and Sneed (1959) induced spawning in the channel catfish and obtained large-scale production of fry by administering human chorionic gonadotrophin (HCG). Ramaswamy and Lakshman (1959), injected a pond catfish with 250 I.U. of chorionic gonadotrophin (known by the trade name of 'Physex') and obtained ripening of eggs. But considering the high cost as compared to fish pituitary hormones, it was not tried in fish culture practices in India. In Russia, as early as in 1947, HCG was used to diagnose pregnancy in women with the fish, loach, as the test animal (Gerbilskii, 1965), but HCG was not immediately used in their regular breeding of sturgeons. With the increase in the demand for pituitaries in recent years and difficulties in their mass procurement, Russian workers felt the need of a substitute which could be produced commercially. 'Choriogonin' (a trade name for CG) was first used in 1964 on loach with great success. Among other possible substitutes, several preparations such as 'Szhk', prepared from pregnant mare serum, 'Estrovet' and 'Hypophysin Forte' were tried by the Bulgarian fish culturists (Bratanov et al., 1963) on carp and trouts (as cited by Gerbilskii, 1965). The authors concluded that these preparations reduce the duration of the spawning process.

Tang (1965), while summarizing the work on induced breeding of Chinese carps in Taiwan, states that treatment with fish pituitaries in combination with chorionic gonadotrophin increases the effectiveness and better success is achieved. Synahorin (CG mixed with certain amount of mammalian pituitary extract) was used with fish pituitaries and 78 percent positive response was obtained. He, however, does not mention the dosage and no systematic experiments were carried out with proper controls to arrive at the conclusion. Fish culturists are using different dosages of Synahorin and fish pituitary glands and each hatchery has its own method.

Results of bio-assay experiments conducted in recent years by Ramaswamy and Lakshman (1960) with trichloroacetic acid (TCA) and a few other chemicals on the glycoprotein content of catfish pituitary gland showed that both the glands immersed for 6 or 12 hours in 1.25 percent TCA and the acid fluid in which they were immersed brought about spawning, but the glycoproteins are extracted and denatured in 12 to 24 hours. TCA of 2.5 percent strength however did not give the desired results. TCA extract of pituitary glands was used at the Central Inland Fisheries Research Institute in India for breeding Indian major carps. Pituitary glands immersed for six hours in 1.5 percent TCA were successful in spawning in 11 out of 12 fish. The minimum effective dose was 14 mg per kg of the fish. Three sets of rohu, when injected with 2.5 percent TCA in which glands were immersed for six hours, did not respond, but when the duration of immersing was reduced to three hours, another three sets could be spawned.

From the foregoing discussion on the various attempts made to spawn fish by hormone treatment, it will be seen that a number of techniques are followed by different workers which produce varying degrees of success. The fish breeder should be able to select the best method suitable for the particular species of fish he breeds. There is, however, ample scope for improvement of the breeding technique by the use of proper bio-assay methods and by chemical standardization of the gonadotrophins.

5 SELECTIVE BREEDING AND HYBRIDIZATION

Carp culture has been a very old practice, especially in India and China. Although the Chinese and Indian carps have been cultured for thousands of years they could not be properly domesticated and they do not differ much in characters from their wild ancestors. The common carp, however, has been domesticated and long-time selection has produced a large number of strains and varieties. This has been possible only because of the fact that unlike the Chinese and Indian carps, the reproduction in common carp can be controlled. The basic need of fish culturists to have better fish for increased production, makes them select the quickest growing, best-shaped and healthiest fish as breeders. Such selection finally results in overall improvement of the stock.

Hybridization is another method of combining desirable qualities and of raising hybrids superior to the parent species. In recent years, study of hybridization in fish has assumed increasing importance in both theoretical and applied ichthyology. In the West, systematic hybridization of various species of salmon and trout has been done (Scott, 1956; Baldwin, 1956; Donaldson _et al_., 1957). In the U.S.S.R., considerable importance is attached to genetics and hybridization work in fisheries. Several inter-racial crosses of sturgeons and both inter-specific and inter-generic hybrids have been produced there (Gerbilskii, 1952; Kazanski, 1953). Hybridization in Chinese and Indian carps, however, could not be done till success in artificial breeding of these fishes was achieved. Chaudhuri (1959b; 1961) first succeeded in producing hybrids in Indian major carps by artificial fertilization of hand-stripped eggs. He obtained 12 different hybrids by crossing carps comprising three genera and six species. Out of these, nine hybrid species were reared to adult size. At least three of the above hybrids showed superior qualities over the parent species. Alikunhi and Chaudhuri (1959) produced a hybrid by fertilizing eggs of an Indian carp (rohu) with common carp sperms and a few specimens grew to adult size. Subsequently Alikunhi _et al_. (1963a; 1963b) succeeded in the hybridization of Chinese carp species and also of Chinese and Indian carps but none of these survived beyond one week. Tang (1965) has reported successful hybridization between bighead and silver carp. These results demonstrate clearly that the hormone injection method has opened a new line of research in selective breeding and hybridization of these economic food fishes of the Indo-Pacific region, with a view to developing improved strains.

5.1 Induced sterility

Sterility may be induced in cultivated fish either by injecting hormones or by hybridization. Control of population density in ponds becomes possible by stocking sterile hybrids. This has far reaching value in scientific fish culture since proper manipulation of stock is essential for obtaining higher production in a pond.

According to Hickling (1962), "Interspecific hybrids, or mules are usually sterile". This may not be true with carps. At the Central Inland Fisheries Research Institute in India an inter-specific hybrid (cross between male _Labeo rohita_ and female _Labeo calbasu_) was bred by hormone injections and produced 40,000 fry of F_2 generation of the hybrids. Even an inter-generic hybrid (cross between _Catla catla_ male and _Labeo rohita_ female) was fertile and could be successfully induced to spawn by hormone injections and thousands of F_2 generation hybrid fingerlings were obtained. Hubbs (1955) however is of the opinion that the great majority of hybrids in nature as well as in captivity are sterile. Such hybrids according to him are predominantly males having abnormal testes and spermatozoa. Hickling's experiment (1960) with Tilapia mossambica demonstrated that when an African male [1] was crossed with a Malayan female the offspring were all males, or nearly so. Although these male hybrids do not show any sign of being either sterile or intersexes, production of all male offspring has considerable significance in fish culture. As already discussed in chapter 4.1.7.1 such hybrids could be profitably used for mono-sex culture of tilapia. Recently, Suzukii (1961) from Japan has reported sterility in artificially produced inter-generic hybrids among bitterlings.

6 SUGGESTIONS FOR FUTURE WORK

Success in induced breeding of the Indian and Chinese carps, by administration of hormones, has greatly helped in large-scale production of pure fish seed, but this is just the beginning and there is vast scope for further improvements. Intensive research directed towards chemical standardization of hormones by proper bio-assay methods has to be carried out and useful data on the sexual cycles, gametogenesis and control of these processes in cultivated food fishes have to be collected in order to perfect the induced fish breeding technique and to improve hatching methods further.

Since hormone treatment in fish culture mainly brings about transition of the fish from fourth stage of maturity to the fifth one, the technique is successfully applied only to fish already close to natural spawning. It can reasonably be hoped that many of the present difficult-to-spawn fish which either attain full maturity in confined waters or the fully mature specimens of which can be collected from their natural habitat, can be bred by hormone injections, provided proper facilities are available The technique has not succeeded in fish whose gonadial condition does not reach the fourth stage in ponds. Even if prolonged hormonal treatment is effective in obtaining the sexual maturity of such fish, it will be difficult to adopt it in commercial fish culture. Further research should, therefore, be directed towards improvement of environmental conditions favouring maturation of gonads or evolving the right type of artificial or natural food which would bring the fish to maturity.

Development of strains of cultivated fish which would be more efficient in food conversion, more resistant to diseases and unfavourable environmental conditions, have quicker growth rates, higher fecundity and earlier maturity, is of vital importance in fish culture in Asia and the Far East. Intensive research work to achieve this is urgently required in the area.

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A REVIEW OF SELECTION AND BREEDING IN THE CULTURE OF WARM-WATER FOOD FISHES IN NORTH AMERICA

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Abstract

Fish farming in the United States today is a rapidly growing industry. Channel catfish (Ictalurus punctatus), blue catfish (Ictalurus furcatus), flathead catfish (Pylodictis olivaris), bigmouth buffalo (Ictiobus cyrpinellus), smallmouth buffalo (Ictiobus bubalus), black buffalo (Ictiobus niger), and the common carp (Cyprinus carpio) are raised for food. The channel catfish is the principal species, being cultured in over 4,000 ha, and at the present demand for fingerlings far exceeds the supply. Their more highly evolved spawning behaviour and rather nervous temperament in hatchery conditions have contributed to a slower mastery of their artificial propagation. Today they can be spawned in ponds, pens or aquaria with or without the use of hormones, as can the other species of catfishes. Successful rearing of the piscivorous flathead catfish has been achieved recently. A great deal of work has been done with induced breeding, but virtually nothing has been accomplished with induced sterility studies with food fish. The long-term growth of oocytes has been achieved by hormone injections and most species can be spawned with a commercially available chorionic gonadotrophin. Other than hybridization of catfish and buffalofish, research in selection has not been scientifically undertaken in any of the warm-water food fishes.

REVUE DES METHODES DE SELECTION ET D'ELEVAGE APPLIQUEES AUX POISSONS ALIMENTAIRES D'EAU TEMPEREE EN AMERIQUE DU NORD

Résumé

La pisciculture est actuellement en plein essor aux Etats-Unis. Diverses espèces y sont élevées pour leur chair: channel catfish (*Ictalurus punctatus*), blue catfish (*Ictalurus furcatus*), flathead catfish (*Pylodictis olivaris*), bigmouth buffalo (*Ictiobus cyrpinellus*), smallmouth buffalo (*Ictiobus bubalus*), black buffalo (*Ictiobus niger*) et carpe cummune (*Cyprinus carpio*). L'espèce la plus répandue est le channel catfish dont l'élevage se pratique sur près de 4,000 hectares, et actuellement la demande d'alevins d'un doigt ("fingerlings") dépasse de loin l'offre. Le comportement relativement évolué de ces poissons au moment de la fraye et une certaine nervosité qu'ils manifestent en bassin d'alevinage ont contribué à ralentir la connaissance des techniques nécessaires à leur propagation artificielle. Aujourd'hui leur reproduction peut s'obtenir en étangs, en enclos ou en aquariums avec ou sans emploi d'hormones; il en est de même pour la reproduction des autres espèces de catfish. Depuis peu on a réussi à élever avec succès l'espèce piscivore "flathead catfish". De nombreuses recherches ont été faites sur la reproduction induite, mais pratiquement rien n'a été accompli jusqu'à présent dans le domaine de la stérilité induite des poissons élevés pour leur chair. On a réussi à provoquer la croissance à long terme des oocytes grâce à des injections d'hormone et on peut provoquer chez la plupart des espèces une fraye artificielle en utilisant la gonadotropine chorionique en vente dans le commerce. A part les travaux sur l'hybridation des catfish et des buffalofish, peu de recherches scientifiques ont été entreprises sur la sélection des poissons d'eau tempérée destinés à l'alimentation.

RESEÑA DE LA SELECCION Y CRIA GENETICA EN EL CULTIVO DE PECES COMESTIBLES DE AGUA DULCE EN AMERICA DEL NORTE

Extracto

La piscicultura en los Estados Unidos es hoy día una industria que crece rápidamente. El bagre del canal (*Ictalurus punctatus*), el bagre azul (*Ictalurus furcatus*), el bagre de cabeza plana (*Pylodictis olivaris*), la carpa común (*Cyprinus carpio*) y dos especies de *Ictiobus*, se cultivan para su consumo comestible. El bagre del canal es la especie principal y se cultiva en más de 4,000 ha, y en la actualidad la demanda de alevines supera a las disponibilidades. Su comportamiento de desove altamente desarrollado y su temperamento bastante nervioso en condiciones de piscifactoría, han contribuído a que se haya practicado menos su propagación artificial. Hoy día puede hacérseles desovar en estanques, recintos o acuarios, con o sin el empleo de hormonas, al igual que sucede con las demás especies de bagres. Recientemente se ha logrado el cultivo con éxito del bagre de cabeza plana que es una especie piscívora. Se ha trabajado mucho en la cría inducida, pero, prácticamente, no se ha logrado nada en cuanto a los estudios de esterilidad provocada referentes a los peces comestibles. El desarrollo a plazo largo de los ovocitos, se ha logrado mediante inyecciones de hormonas, y la mayoría de las especies pueden hacerse desovar con una gonadotropina coriónica disponible comercialmente. Aparte la hibridación de bagres e *Ictiobus*, la investigación en materia de selección no se ha realizado científicamente para ninguna de las especies comestibles de aguas cálidas.

1 INTRODUCTION

There are relatively few warm-water species of fish cultured for food in North America today. The most commonly reared fish are channel catfish (Ictalurus punctatus), buffalofish (Ictiobus spp.), and carp (Cyprinus carpio). Interest is being shown in the culture of the flathead catfish (Pylodictis olivaris), the blue catfish (Ictalurus furcatus), and the white catfish (Ictalurus catus), and these species are being raised on an experimental basis.

There is a great deal of information available on induced spawning, but no significant studies appear to have been made on induced sterility. To my knowledge, no selection program is being carried out using definite criteria, careful selection, and complete records. Since hatchery-reared brood stock is extensively used, selection has occurred under the normal culture conditions. There is one extensive study on hybridization of various species of North American catfish in progress and another on the hybridization of buffalofish. Warm-water fish, as far as I can determine, are not being cultured for food on a large scale at the present time in Canada (Smith, 1961), Mexico, or Central America.

2 PROPAGATION

2.1 Channel catfish (Ictalurus punctatus)

The highly evolved spawning behaviour of the channel catfish has presented numerous problems to the culturist. Its relatively nervous temperament has made the fish difficult to spawn under hatchery conditions, so the culturist has had either to collect brood stock from lakes and streams just before spawning time (Lenz, 1947) or to acclimatize his breeders for two or more years (Marzolf, 1957).

In the selection of brood stock the culturist has had taxonomic problems in distinguishing the channel catfish from the closely related blue catfish. He has had trouble in sexing the fish in order to reach a workable sex ratio for breeding. The culturist has had to learn how to handle his fish to minimize the fighting which results from pairing during the breeding season. Also, he has had to consider the role of the male in his management procedures, since in nature this parent cares for the eggs.

Culturists today prefer brood stock from two to 10 pounds (0.9 - 4.5 kg), hatchery-raised if available, with equal numbers of males and females. In pairing the fish, Clemens and Sneed (1957) concluded that males of comparable size to the females should be used, but most culturists (Murphree, 1940; Toole, 1951; Crawford, 1958; Nelson, 1960; and others) prefer or even require that the male be slightly larger than the female. Sneed (personal communication) recommends that breeders be stocked at the rate of 300 to 400 pounds (333 - 444 kg/ha) for 2 to 3 pound (0.9 - 1.35 kg) breeders where growth is desired. Where growth is not expected, the stocking rate can be doubled. Fish should be fed two to three percent of their body weight three to four days a week when the temperature is above 55°F (12.7°C). It is generally accepted that fresh or frozen meat or fish should be part of the diet.

Egg numbers have been reported by various authors (Doze, 1925b; Clapp, 1929; Menzel, 1945; Canfield, 1947; Crawford, 1958; Geibel and Murray, 1961), and their reports agree with that of Clemens and Sneed (1957) that females which weighed from one to four pounds (0.5 - 1.8 kg) produced about 4,000 eggs per pound (0.45 kg) of body weight. Channel catfish eggs are deposited in a pile which is yellow in colour and turns red as the eggs approach hatching. The fry, when hatched, number from 750 to 1,300 per ounce (0.14 kg)(Bishop, personal communication).

The period of incubation ranges from five to ten days at temperatures between 70° and 80°F (21 - 26°C). Three days after hatching, the fry start to feed and move about.

2.1.1 Spawning methods of channel catfish

Channel catfish can be spawned in ponds, pens, or aquaria with or without the use of hormones. In the pond method (Doze, 1925a; 1925b; Clapp, 1929; Mobley, 1931; Brown, 1942; Canfield, 1947; Lenz, 1947; Snow, 1960; Geibel and Murray, 1961; Bishop, personal communication) an equal number of males and females are placed in a pond at a stocking rate of 24 to 150 fish per acre (59 to 470/ha). Ten-gallon (45 litre) milk cans or large drums are placed in the pond as spawning receptacles so that there is one receptacle for two pairs of fish, or three receptacles for four pairs of fish. If the culturist plans to move either fry or eggs to nursery ponds to insure better stocking control, he checks the receptacles regularly. If he does not move fry or eggs from the pond, the brood stock are sometimes removed after spawning to minimize the transfer of disease from the adult to the young fish.

In the pen method (Mobley, 1931; Toole, 1951; Nelson, 1957; Crawford, 1958; Snow, 1960;, Bishop, personal communication), one pair of fish is placed in a small pen, one of a series of wire fencing pens built along the sides of a pond, each of which is provided with a spawning receptacle. The pen protects the spawning pair from intruding fish and gives the culturist an opportunity to select members of each pair, to delay or hasten spawning, to handle the fish needing hormone injections, and to remove them immediately after spawning so that the pen may be restocked with another pair.

In the aquarium method, a pair of fish is placed in an aquarium with running water and is induced to spawn by the injection of hormones (Sneed and Clemens, 1960a). Here, spawn may be obtained at a time desirable to the culturist, and fish which will not spawn naturally sometimes may be induced to spawn. The aquarium method provides the culturist with eggs and fry which are uniform in age and size, minimize the transmission of disease from parent to offspring, and eliminates predation by adults (Sneed and Clemens, 1960b).

The three spawning methods have different applications according to the skill of the culturist, the quality and quantity of brood stock, and the availability of facilities. The pond method is the least demanding from the standpoint of time, effort, facilities, and skill. It has special use when the brood stock is of marginal quality (Snow, 1960) or when sufficient spawning ponds are available to spawn large numbers of fish with limited and unskilled manpower. The pen method requires better quality brood stock and personnel capable of properly sexing and pairing the fish. The aquarium method should be attempted only by the skilled culturist who desires to increase his rate of production during the short spawning season or when the pen or pond method is not successful.

2.1.2 Hatching methods

After spawning, the eggs are left in the care of the male or are removed to a mechanical hatching trough provided with running water and a system of moving paddles for agitation (Morris, 1939; Nelson, 1960; and others).

2.1.3 Rearing methods

Fry may be reared in a trough or in ponds. The troughs are usually 240 - 300 cm long, 20-50 cm wide, and 30 cm deep, and are supplied with running water, a drain, and a standpipe. Fry from one or two spawns are placed in a single trough, and feeding begins between the third and fifth days. Fry can be raised to fingerlings in troughs, or they may be moved to a pond at any time.

Rearing ponds for channel catfish vary in size from 1/10 to 5 acres (0.04 to 2 ha). The pond is usually filled immediately before stocking to prevent the establishment of predaceous insects. Fry may be released directly into the pond, or afforded protection for a few days by a wooden box with a finely screened bottom. Stocking rates vary from 50,000 to 250,000 per acre (120,000 to 600,000/ha) since the fish are fed and are to be harvested as fingerlings.

2.2 Flathead catfish (*Pylodictis olivaris*)

The piscivorous flathead catfish can be spawned by using methods applied to channel catfish. Previous difficulties have been due to the poor or inadequate condition of the brood stock (Henderson, 1963) resulting from improper feeding or lack of sexual maturity. A great deal of information is needed yet about all phases of culture of this fish.

Culturists have had great difficulty in getting the fry started on feed (Snow, 1959; Sneed *et al.*,1961; Giudice, 1963; Moen, 1964), but this has been largely overcome. Recently Sandoz (personal communication) has described a satisfactory method of feeding newly hatched flathead catfish fry in troughs. A paste of liver, powdered milk, and egg yolk is spread thinly on the bottom of a board which is floated in the trough. Fish hiding in the shadow of the board are in range of the scent of the food, and they immediately feed. The paste is replenished as needed.

2.3 Blue catfish (*Ictalurus furcatus*)

Blue catfish require the same care, spawn at the same time and at the same temperature as channel and flathead catfishes and, therefore, are handled similarly. There is less fighting among blue catfish, they feed better than channel catfish, and they come to the surface more readily (Sneed and Martin, personal communication).

2.4 White catfish (*Ictalurus catus*)

Although the white catfish is not being raised for food at the present time, many aspects of its culture have been studied, particularly by Prather and Swingle (1960) and at the Southeastern Fish Cultural Laboratory of the U.S. Fish and Wildlife Service. It is the easiest of all catfishes to raise and responds to the culture techniques of the channel catfish. It is more resistant to low oxygen than other species, and lives exceptionally well during harvesting operations. Food conversion values are higher in white catfish than in channel catfish.

2.5 Carp (*Cyprinus carpio*)

Carp are not generally considered desirable fish in the United States and have limited sales at a relatively low price. However, when raised in ponds and fed well, the flavour compares favourably with that of other species, although the numerous small bones limit the usefulness in the restaurant trade (Swingle, 1954). Swingle reports on the propagation procedure. Brood stock are carried through the winter in ponds stocked at rates up to 2000 pounds per acre (5,000 kg/ha). They are fed 2 percent of their body weight per day while the water temperature is above 50°F (10°C). In March small ponds, approximately 1/10 acre (0.04 ha) are filled with water from a stream or pond that does not contain carp and are stocked with two pairs of brood carp when the water temperature reaches 65° to 70°F (18°-21°C). Eggs are usually laid the next morning on submerged grass at the sides of the pond. Eggs hatch in three to five days. Two to four weeks after hatching, carp are transferred to nursery ponds at the rate of 10,000 per acre (250,000/ha). Ponds are fertilized regularly during the summer.

Carp can be injected dried pituitary material at the rate of 2 to 3 mg per pound (0.45 kg) of body weight, and the sexes can be handstripped 18 hours after the injections. The sexes are kept separate during this period. Eggs are handstripped into a plastic container, and sperms are added and mixed with the eggs. Small quantities of water are slowly added to mobilize the sperms, and just as the eggs begin to swell and adhere, they are dispersed with a nylon or plastic point brush over a submerged spawning mat (Clemens and Sneed, 1962). The spawning mats can then be moved to nursery ponds. This method has the advantages of hormone spawning described elsewhere in this review, and it also can be applied to buffalofish and goldfish.

The Israeli strain of common carp thrives under culture conditions and grows extremely fast but is more difficult to spawn than the common strain of carp.

2.6 Buffalofish (*Ictiobus* spp.)

The principal species of buffalofish cultured for food in the United States is the bigmouth buffalo (*Ictiobus cyprinellus*). Two other species are produced to a lesser extent: smallmouth buffalo (*Ictiobus bubalus*), and black buffalo (*Ictiobus niger*). In the United States various aspects of buffalofish culture have been reported by Shira (1917), Canfield (1922), Walker *et al.* (1952), Hogan (1953), Swingle (1953; 1954; 1956 and 1957), Wood (1953), Hogan and Stevenson (1954), Hendricks (1956), Stevenson (1957), Brady and Hulsey (1959), Johnson (1959), and Hulsey (1964). Giudice (1964) has hybridized buffalofish, and certain hybrids grow faster than the parent species by as much as 33 percent by weight.

Buffalofish are cultured in the same way as carp. Two to four pound (1 - 2 kg) fish are preferred for breeding.

3 INDUCED BREEDING

3.1 Commercial application

The use of pituitary materials in North America to induce fish to spawn has many advantages in the culture of sport, food, bait, and tropical fishes (Clemens and Sneed, 1962). Since fully ripe females of most species respond to pituitary injections by spawning within 12 to 20 hours, it is possible to predict rather accurately when spawning will occur. This predictability allows the fish culturist to plan his work according to a rigid schedule, since the injections to some degree bypass the environmental variable of temperature, light and rain. Both males and females respond positively to pituitary injections so most species can be handstripped, a practice which offers additional advantages. Culture ponds can be stocked with eggs and fry of uniform age and size. Since the brood stock are not in the pond with the offspring, the possibility of disease transmission from brood stock to offspring is reduced, and predation by the parent is eliminated. Hybrids can often be produced by handstripping. Wild fish that have not been domesticated may be spawned more easily by the pituitary method. Frequently, a more uniform spawning has been achieved by the injection of pituitary materials into ripe fish which, because of some environmental or physiological condition, would fail to spawn without such treatment.

3.2 Experimental considerations

Pickford and Atz (1957) reviewed all the available literature on the pituitaries of fish. Later, Atz and Pickford (1959) reviewed the use of pituitary hormones in fish culture, and in 1964 they prepared an annotated bibliography on the pituitary gland and its relation to the reproduction of fishes in nature and captivity. A study of the Pickford and Atz book, indispensable to anyone interested in fish gonadotrophins and their use in fish culture, reveals:

(i) Fish pituitaries contain the hormones necessary to precipitate spawning in ripe fish.

(ii) There is little if any specificity in the hormones of fish; that is, the pituitaries of one family or species are usually active in unrelated species.

(iii) There are a number of examples in which gonadotrophic materials from other vertebrate classes were found to be active in fish.

(iv) Out-of-season spawning has been induced by the administration of gonadotrophins.

(v) Fresh, acetone-dried, or frozen pituitaries, as well as glycerine extracts, saline suspensions, and water extracts have similar activity.

(vi) Under most experimental conditions the injection of pituitaries does not decrease fertility.

(vii) Increased or decreased exposure to light (depending on species of fish involved) may have the same effect on sexual development and spawning as pituitary injections.

(viii) There is little or no qualitative difference in the pituitaries of the male and female donor fish, at least from the practical viewpoint.

(ix) There may be a seasonal difference in the biological effect produced by the pituitaries taken from fish prior to spawning and those taken immediately after spawning.

Since 1957 more information has been added, and some of the earlier ideas have been modified. A relatively quick and sensitive assay using fish has been developed to detect the principle in fish pituitaries that is responsible for ovulation in the female and seminal production in the male (Clemens and Grant,1964;1965). Clemens and Johnson (1964) used this assay to re-examine the problem of specificity. These workers examined the response of goldfish to pituitary material from 20 species of vertebrates representing 17 genera, 13 families, 8 orders, and 5 classes. They concluded that the magnitude of response roughly approximated the phylogenetic closeness of the donor to the recipient. Fish culturists should be encouraged to use pituitaries from phylogenetically close donors when a choice can be made. If, however, the donor and the recipient are rather distantly related, the dosage should be increased slightly.

Handling has been shown to have a direct effect on the gonadal processes of both male and female carp and goldfish, but the resulting stress is overcome by the injection of pituitary materials (Clemens and Grant, 1964). To a fish culturist this observation re-emphasizes the value of hormones in spawning wild fish.

The importance of food on gonadal processes was demonstrated by Clemens and Grant (1964) when goldfish starved for five days required 16 days with food to regain their original gonadal condition. Further studies (Clemens and Reed,1966a) show that fish kept on a maintenance diet for 60 days temporarily lose their powers of gonadal development. That is, the gonads of such fish do not develop in the expected manner when the fish are placed on a growth diet. This observation suggests at least a temporary impairment of gonadotrophic function of the pituitary.

Clemens and Grant (1964) showed that there was an optimum temperature with respect to dosage of hormones. The culturist should provide optimum temperatures for fish during both the gonadal development and spawning periods.

Long-term growth of oocytes (from oogonia to ripe ova) was induced in goldfish by a bi-weekly injection of partially purified fish gonadotrophins with six to 12 times an average spawning dose (Clemens and Reed, 1966b). Thus gonadal development can be induced as well as spawning. The hastening of fish into spawning, the attainment of more spawns in a given interval of time, and in short a more regulated control of the gonadal processes is suggested.

Since the pituitary size of goldfish and channel catfish varies directly with the size of the fish, it is important for the culturist injecting on a gland basis to use a gland from a fish of similar size (Clemens and Reed, 1962).

Although differences in gonadotrophic activity may exist according to sex of the donor or season collected, these differences appear to be insignificant in fish cultural practices when pituitaries are injected on a weight basis (Clemens and Sneed, 1962).

3.3 General techniques

A review of the attempts to spawn fish by hormones reveals a number of techniques which produce varying degrees of success. The reason that a proper and proved technique may produce negative results lies to some extent with the qualifications of the investigator, who is usually either an endocrinologist who knows almost nothing about fish culture, or a fish-culturist who is rather uninformed about endocrinology. For this reason, we regard only positive results in the reports of induced spawning experiments as truly significant. Sometimes even the positive results need to be regarded with caution since fish can occasionally be chemically or physically shocked into spawning.

The condition of the female fish at the time that induced spawning experiments are conducted is of utmost importance. The method described by Clemens and Sneed (1962) concerns spawning of ripe fish only, while the special techniques of Clemens and Reed (1966b) are required to hasten unripe fish into spawning. Likewise fish slightly delayed in spawning, or refractive to spawning in the natural habitat, can be spawned by the methods of Clemens and Sneed (1962) which are discussed here.

The best method of selecting fish for advanced sexual development is to examine the fish carefully. The assessment of the females' physiological receptivity to gonadotrophins should be based on a combination of the following characteristics: (i) abdominal distention by the ovaries, preferably after the digestive tract has been emptied;(ii) condition of the genital opening; (iii) colour; (iv) degree of abdominal flaccidity; and (v) behaviour.

The assessment of the degree of sexual development of the male is not usually a major problem. During the spawning season, males of many species often show sexual dimorphism, and any male in breeding colour is assumed to be ripe. If sexual dimorphism does not exist, and it is difficult to determine ripe males from unripe females and immature individuals, the fish of undetermined sex can be stocked at a ratio of two or more per gravid female in an effort to assure the presence of some mature males. These fish should be similar in size to the selected gravid females. In those species that pair, the behaviour of the male frequently indicates whether or not he is a potential spawner. His positive or negative attitude towards the female or to other males often reflects his sexual development. A thorough knowledge of the natural spawning behaviour and conditions for the particular species makes it much easier to select fish that can be induced to spawn. Both males and females are usually injected for handstripping procedures, but otherwise only the females receive gonadotrophins. For species that require more specific environments for spawning, such as the nest builders, it may be necessary to provide certain facilities such as vegetation, gravel, rocks, cans or flowing water. Stimuli from the environment may also play an important role in the proper metabolism and in the activity of the injected hormones.

Other important factors of general technique to be considered include the collection of pituitaries, dosage, and handling. Pituitaries may be collected from culled brood stock or other fish and used in fresh condition. They may also be collected prior to the time they are to be used, dehydrated in acetone, and stored in a dried condition. Fresh-frozen pituitaries are equally satisfactory. In using pituitaries, very little or no attention is paid to the sex of the donor fish or to the season in which they were collected. However, pituitaries of various species are usually kept separate.

It usually saves time and labour to give doses above the minimum required for spawning rather than to administer a subminimal dose. The evidence indicates that once the spawning dose is reached, greater amounts of pituitary do not change the results.

Needle sizes from 19 to 21 are satisfactory and do not often clog. Luer-lock hypodermic syringes, which have a locked needle, will prevent the loss of materials if the needle clogs. Large fish are usually not anaesthetized. They are injected intraperitoneally with pituitary dosages of two mg or more of acetone-dried whole ground pituitary per pound (0.45 kg) of body weight, with one ml or more of distilled water. Ten thousand units of penicillin may be used to combat infection if multiple injections are necessary.

Human chorionic gonadotrophin, obtained from the urine of pregnant women, is commercially prepared and available at drug-stores throughout the country. It has been found to be active in many species of fish, namely channel catfish, goldfish, and white crappie (Sneed and Clemens, 1960b), trout (Salmo gairdneri) (Clemens and Grant, 1964), striped bass (Roccus saxatilis) (Stevens, 1964), paddle fish (Meyer and Stevenson, 1962), flathead catfish (Sneed, Dupree and Green, 1961), blue catfish, and white catfish (Sneed, personal communication). It can be obtained in liquid or powder form at a price which is comparable to fish pituitaries. Veterinarian grades are suitable and less expensive.

Suitable facilities and proper spawning places (such as well-aerated running water, aquaria, troughs, pens or ponds) must be provided, the type depending on the species to be spawned. If a question of water temperature arises, a temperature approximating that at which spawning occurs in nature is used. In such species as carp and goldfish where there is a danger that the eggs will be eaten, the fish can be made to spawn on mats which are moved periodically to hatching ponds or troughs. The egg masses of the catfishes are easily moved to mechanical hatching facilities immediately after spawning is complete.

The response of a particular species of fish to pituitary injections varies with the gonadal development of the fish. Very gravid females respond much more readily than the fish less well-developed. In other words, it is easy to induce spawning during the regular spawning season, and the fish often spawn with one injection; whereas fish injected a few weeks before their regular spawning season may require several injections over a period of hours or days in order to precipitate the spawning act. Usually several injections must be used to spawn fish past their normal spawning period, but spawning cannot be obtained if degeneration of eggs has begun. Usually delayed fish are refractory, but quite often normal eggs can be procured if several low-level dosages are given. Apparently the major requirements for successful induced spawning are fish that contain well-developed eggs and injected pituitaries which contain the components necessary to precipitate the spawning act or to produce ovulation. In many species, sperm is available in at least some males most months of the year. Immature fish respond abnormally to materials similar to those injected into mature fish.

4 SELECTION

Riggs and Sneed (1959) reviewed the subject of genetic selection in fish culture in the United States and emphasized the role of physiological research. They point out that it is surprising that fish culturists have not experimented more with selective breeding of the species commonly propagated in American hatcheries, since it is obvious that so much is to be gained from such research. Undoubtedly two of the principal deterring factors are lack of proper facilities and inadequately trained personnel at a large percentage of the state and federal hatcheries. For the most part selective breeding has involved cold-water species. Donaldson and Olson (1957) discussed breeding experiments conducted on rainbow trout for 22 years which have improved growth rate, age of maturity, resistance to disease, tolerance to warm water, and egg production. There have also been several papers on experimental hybridization of both warm- and cold-water fishes in many parts of the country, but none are concerned with warm-water food fish.

Further, Riggs and Sneed (1959) point out the problems that confront the fish culturist who attempts research on selective breeding. They are (i) variation in spawning time; (ii) peculiarities of spawning behaviour; (iii) peculiarities in environmental requirements for spawning, particularly space, visual and tactile stimuli; and (iv) uncertainty of regular spawning. Such problems should all be solved by the proper use of hormones as they have been in the case of the channel catfish.

Riggs and Sneed (1959) cite the goals of any good hatchery as: (i) greater efficiency and economy of operation; (ii) greater egg production with a greater production of fish; (iii) greater resistance to disease and parasites; (iv) faster growth; (v) earlier sexual maturity. A successful program of selection can help achieve these goals. Greater efficiency and economy should result from greater production, less space requirements, fewer brood stock, lower mortality rates, and shorter periods of maintaining those fish produced. Hormone injections and genetic selection will bring about year-round production of any species, especially if light and temperature can be controlled.

Smith (1961) in his review on the selectivity and hybridization in management of fish stocks notes that in a relatively stable and protective environment, such as a hatchery, a new set of conditions is provided where artificial selection makes possible a more rapid genetic shift than is likely to occur in the natural state. Intensive and continuous artificial selection may therefore result in observable changes in a relatively short period of time.

Criteria need to be set up for selection practices in the culture of each species. More studies on hybridization are needed. Although this subject will be treated in another part of the symposium in greater detail, a few statements need to be made here.

The fact that hormones can be used to induce ovulation and seminal production has led the way to hand-fertilization techniques. Such a technique for carp and goldfish has been described by Clemens and Sneed (1962) and is reviewed in the carp section of this paper. The freezing and storage of fish semen will enhance this technique still further although more research is needed (Sneed and Clemens, 1956).

Dupree, Green, and Sneed (1965) learned to ovulate the various species of catfish and to handle the eggs. They report that the female of a species to be crossed is injected with a spawning dose of HCG and placed with a male of the same species in an aquarium. When the first signs of spawning behaviour are noticed, the female is removed and stripped after a waiting period of half an hour. This permits more eggs to ovulate and at the same time they do not lose their viability, which occurs when catfish eggs remain an hour or more in ovarian fluid. Since male catfish cannot be stripped, a male of another species must be sacrificed, the testes removed and macerated in an appropriate concentration of frog Ringers solution. The macerated testes are added to the eggs as they are stripped into a small amount of water. The eggs are swirled over a piece of polyethylene plastic and allowed to settle to the botton where they adhere. With this technique they have obtained hybrid crosses from both male and female combinations of the following: channel catfish (*Ictalurus punctatus*), white catfish (*Ictalurus catus*), blue catfish (*Ictalurus furcatus*), flathead catfish (*Pylodictis olivaris*), black bullhead catfish (*Ictalurus melas*), yellow bullhead catfish(*Ictalurus natalis*), and brown bullhead catfish (*Ictalurus nebulosus*). Crosses in which the female flathead were used all proved unsuccessful. The embryos died before hatching or shortly afterwards. When the male flathead was used in hybridization, it proved successful in four other species that were tried.

In this study 15 hybrids have been produced from seven parent species. Each hybrid is being studied and evaluated for use in fish cultural practices.

I have an oral report that a female blue catfish and a male channel catfish have been spawned without hormones. Another report was made of a cross between a blue and a channel catfish. However, experiments are needed to determine whether or not crosses can be obtained without the use of hormones and handstripping methods.

Hand-fertilization methods make it possible to divide the semen and ova into a number of portions and to obtain several crosses from individual fish at one time. Facilities and suitable marking techniques are needed to promote these studies. These techniques will be of great advantage to the geneticist because they give him the means to speed up study of fish genetics.

The three species of buffalofish have been hybridized by Giudice (1964) with hormones and handstripping methods. Only black x bigmouth spawned naturally without hormones in the pond. He reports that the hybrids grow faster than parent species, as much as 33 percent by weight for black x bigmouth.

In the United States albino channel catfish (Nelson, 1958; Prather, 1961) occur and these fish have been selected and bred. Such fish are at present a curiosity and bring a higher market price, but probably they do not have any more value as a commercial fish. Lately, I have received reports from the U. S. Experimental Fish Farm in Stuttgart, Arkansas, that albino flathead catfish are being raised in that state.

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This review summarizes a comprehensive treatment of the subject in which details of breeding techniques, current practices, and other related fields are examined.

CRIA Y SELECCION DE LOS PECES CULTIVADOS EN AGUAS TEMPLADAS EN AMERICA DEL SUR Y CENTRAL

por

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Extracto

La cría y selección de peces nativos en aguas templadas cultivados con objetivo comercial es prácticamente desconocida, sin embargo, en estaciones de piscicultura se ha realizado esta actividad. En Brasil, el método de hipofisación ha sido aplicado para la inducción artificial de la cría de algunos peces en las estaciones de piscicultura del Gobierno. Los alevines obtenidos por este método son destinados a la plantación en embalses donde se practica la piscicultura extensiva. En Guatemala se cultivan ocho especies del género Cichlasoma. En Brasil, tres Cichlidae carnívoros se reproducen en estaciones de piscicultura del gobierno pero no se emplean en la piscicultura comercial, así como dos especies carnívoras de agua dulce. En Perú, se reproduce el paiche o piraducu, en tres estaciones de piscicultura. Las dificultades presentadas por estos peces nativos para la piscicultura comercial determinaron la introducción de peces exóticos como carpa, tilapia y lubina.

IV/R-5

BREEDING AND SELECTION OF FISH RAISED IN TEMPERATE WATERS IN CENTRAL AND SOUTH AMERICA

Abstract

Temperate-water indigenous fish have been bred and selected at pisciculture stations, but practically nothing has been done on a commercial scale. In Brazil, fish at government pisciculture stations have been induced to spawn by means of pituitary injections. The fry obtained by this method are introduced into reservoirs exploited for large-scale fish farming. In Guatemala eight species of the Cichlasoma genus are reared. In Brazil three carnivorous fish of the family Cichlidae are bred at government pisciculture stations, but they are not used in commercial fish farming; this is also the case for two fresh-water carnivorous species. In Peru, the "paiche" or "piraducu" is raised at three pisciculture stations. The difficulties involved in using these native fishes in commercial fish farming may lead to the introduction of exotic fish like carp, tilapia and bass.

REPRODUCTION ET SELECTION DES POISSONS ELEVES EN EAU TEMPEREE EN AMERIQUE DU SUD ET EN AMERIQUE CENTRALE

Résumé

La reproduction et la sélection à des fins commerciales de poissons originaires des eaux tempérées sont pratiquemment inconnues; néanmoins, des expériences ont été réalisées dans des stations de pisciculture. Au Brésil, la méthode de l'injection d'extrait d'hypophyse a été appliquée pour provoquer le frai artificiel de certains poissons dans les établissements de pisciculture de l'Etat. Les alevins obtenus grâce à cette méthode sont déstinés à l'empoissonement des lacs de barrage où se pratique une pisciculture extensive. Au Guatémala, on élève huit espèces du genre Cichlasoma. Au Brésil, on élève dans les établissements de pisciculture de l'Etat trois Cichlidés carnivores qui ne sont pas employés en pisciculture commerciale, ainsi que deux espèces carnivores d'eau douce. Au péru, on élève le "paiche" ou "piraducu" dans trois établissements de pisciculture. Les difficultés que présentent des espèces indigènes pour la pisciculture commerciale ont conduit à l'introduction de poissons exotiques comme la carpe, le tilapia et la "lubina".

1 LOS PECES NATIVOS

Durante los trabajos del "Centro Latino-Americano de Capacitación en Piscicultura y Pesca Continental", auspicado por el Ministerio de Agricultura de la República de Colombia y la FAO de las Naciones Unidas (Buga, Colombia, 1 febrero - 11 marzo, 1960), dijo el profesor Lin: "Nuestro conocimiento sobre los hábitos de los peces de América Latina, su alimentación, reproducción y adaptación al cultivo doméstico son rudimentarios... Los peces de la familia Characidae exigen condiciones que no es posible reproducir en estanques y pequeños lagos (migraciones y otras desconocidas)... No ha habido hasta ahora un cultivo comercial, de ninguna de las muchas especies de esta importante familia, aunque en el Brasil se ha inducido la reproducción de algunas de ellas en reducida escala por medio de la inyección de estracto de hipofisis a hembras y machos maduros, pero es tal vez discutible si este procedimiento de laboratorio realmente es aplicable a la piscicultura práctica."

El llamado "método de hipofisación" ha sido aplicado, en el Brasil, para la inducción artificial de la cría de algunos peces en las estaciones de piscicultura del gobierno. Los alevines obtenidos por el método son destinado a la plantación en embalses donde se practica la piscicultura extensiva (*Prochilodus*, *Leporinus*, *Curimata*, *Triportheus*, de la familia Characidae; y *Trachycorystes*, de la familia Auchenipteridae), en el Nordeste del Brasil. Las informaciones básicas del "método de hipofisación" son presentadas por Pickford y Atz (1957) y Atz y Pickford (1964). Sin embargo, el método no ha sido aplicado a la piscicultura comercial. En la Estación de Piscicultura de Amanari (municipio de Maranguape, Estado de Ceará, Brasil), el biólogo João de Liveira Chacon obtuvo, por el método de hipofisación, la hibridación de una especie del género *Prochilodus* con una especie del género *Leporinus*.

Lin (FAO/UN, 1963a) presenta los resultados de investigaciones hechas en Guatemala con el cultive do ocho especies del género *Cichlasoma* (otra grande familia Cichlidae), que se reproducen espontáneamente en estanques (al contrario de los Characidae). Llegó a la conclusión de que las ocho especies tienen desarrollo sumamente lento, producción baja y no son económicamente convenientes.

En el Brasil, hay tres Cichlidae carnívoros - *Astronotus ocellatus*, *Cichla ocellaris* y *C. temensis* - que se reproducen en los estanques de las estaciones de piscicultura del gobierno, pero que no son empleados en la piscicultura comercial. Lo mismo puede ser dicho en relación a dos especies carnívoras de agua dulce, de la familia Sciaenidae, *Plagioscion surinamensis* y *P. squamosissimus*. Estas cinco especies son, como los Characidae, destinados a la plantación en embalses, para la piscicultura extensiva.

En el Perú, en la región del Oriente, existen tres estaciones de piscicultura - Rimache, Sumiria y Pacaya -, dedicadas a la reproducción de alevinaje del paiche o piraruou, *Arapaima gigas*, con cuya producción se está repoblando los ríos del Oriente, para dar alimento a los selvícolas de la región (informe de J.E. Hernandez y Carlos Moreno R., en el "Centro de Buga, Colombia", citado en el primer párrafo).

Moe, Jr. (1964) cita tres relatos sobre tres especies de la piraña, *Serrasalmus* (un carnívoro peligroso de América del Sur), que desovarán en cautiverio, en los Estados Unidos de América del Norte, bajo los cuidados de piscicultores de acuario: *S. spilopleura* (tres años en cautiverio antes del desove), *S. nattereri* (alimentación con ratones vivos para ser mantenido en condiciones de desove) y *S. niger*, de la familia Characidae. Estos hechos muestras las posibilidades de reproducción en cautiverio de otros peces de la familia Characidae, por medio de alimentación adecuada, modificación del medio acuático, etc. En Brasil, por ejemplo, tres Characidae (*Curimatus elegans*, *Astyanax bimaculatus* y *A. taeniatus*) se reproducen en cautiverio cuando mantenidos en un acuario con agua corriente, estando los peces sexualmente maduros (Ihering y Azevedo, 1937; Azevedo y Oliveira, 1939).

Los servicios de pesca y piscicultura en América del Sur y Central cuentan con pocos investigadores para el estudio de la cría y selección de su riquísima fauna de peces nativos de agua dulce templada. Estos servicios deben trabajar en articulación con las universidades, a las cuales se deben dar becas para investigadores universitarios - así como la donación de medios materiales - que deseen investigar el inmenso campo de estudio de la reproducción de esos peces nativos. Una vez establecidos los principios de tal reproducción en cautiverio, los servicios de pesca y piscicultura rural, por medio de los servicios de extensión agrícola. Sería sumamente indicado que la FAO tenga en consideración estas sugerencias y, en el caso de aprobarlas, las apoye por medio de sus oficinas en América del Sur y Central.

2 LOS PECES EXOTICOS

Las dificultades presentadas por los peces nativos a la piscicultura comercial, en América del Sur y Central, determinarán la introducción de peces exóticos cuya utilización haya sido largamente comprobada. Entre los peces exóticos citamos la carpa, Cyprinus carpio (diversas variedades); diversas especies del género tilapia (Tilapia mossambica, T. melanopleura), conocidas vulgarmente por tilapias; la lubina negra de boca grande o "black bass", Micropterus salmoide. Respecto a esta última especie, informa Godoy (1959) la ausencia de su exploración comercial en Brasil.

Lin (FAO/UN, 1963a), tratando del cultivo experimental de una especie mejor de carpa de espejos procedente de Israel e introducida en Guatemala, El Salvador y en México, dice que se desarrolla excelentemente en las zonas comprendidas entre los 500 y los 2.000 metros de altitud, donde la temperatura del agua oscila entre 18 y 26°C. Cita producciones brutas por hectárea y año de 3570 Kg, en un estanque de San Antonio Jutes, en Guatemala.

Tratando del cultive de la carpa en El Salvador, dice Lin (FAO/UN, 1963b) que, en las condiciones de Santa Cruz Porrillo, especialmente debido a la temperatura del agua uniformemente alta junto con el consiguiente menor contenido de oxígeno en el agua y la presencia de una cantidad excesiva de peces indígenas que compiten por el alimento, la carpa hembra no desarrolla los huevos normal y completamente como en un clima más suave. Y anuda: "Como resultado de tales influencias del ambiente, el desove no es satisfactorio e incluso la supervivencia de las crías es baja. Se ha logrado alguna mejora en el desove de las carpas mediante la selección de individuos aclimatados y una cuidadosa filtración del agua, pero para conseguir resultados más satisfactorios se necesita trabajar más en el sentido indicado".

Respecto a la Tilapia melanopleura en Brasil, Godoy (1959) refiere una producción de 10.000 Kg por hectárea y por ano, en un estanque pequeno de 40 metros cuadrados, con la profundidad media de 25 centímetros, en la ciudad de Pirassununga, estado de São Paulo. Las tilapias fueron alimentadas con sobras de comidas, intestinos de aves de corral, hojas de vegetales (gramíneas, Maniot, Ipomoea batatas, Sechium edule).

En 1964, la "Resolución número 0217", del Ministerio de Agricultura de Colombia, prohibe la cría y el cultivo de la carpa en aquel país, estableciendo que la "División de Recursos Naturales adelantará los programas necesarios para reemplazar tal especie y sus variedades por aquéllas que técnicamente sean recomendables". La justificación es la inconveniencia de dicha especie que "al propagarse en aguas libres afectaría en forma inconveniente el equilibrio biológico de la fauna acuática". Esta inconveniencia no ha sido comprobada en las aguas naturales de otros países, como en Brasil (informaciones de especialistas del estado de São Paulo) o en Guatemala. Según Lin (FAO/UN, 1963a), en este último país, las carpas utilizadas para poblar los ríos y lagos a partir de 1926 se han capturado rara vez o bien han desaparecido completamente, como ha sucedido en los lagos de Amatitlán y Atitlán y en el río Motagua, donde rara vez se ha señalado la presencia de carpas; y anuda: "no se han oído nunca quejas de que la fauna íctica de esas aguas se haya modificade como consecuencia de haberlas poblado con carpas".

Sin embargo, la Resolución citada de Colombia probablemente tendrá la ventaja de intensificar el estudio de la cría y selección de peces indígenas, con el objetivo de su piscicultura comercial. En el estado de São Paulo, Brasil, la cría comercial de carpas se hace en escala regular, principalmente por los japoneses y sus descendientes.

3 CONCLUSIONES Y RECOMENDACIONES

La cría y selección de peces nativos o indígenas cultivados de agua templada (incluída la cría inducida y la esterilidad inducida), con objetivo comercial, en América del Sur y Central, por la utilización de métodos de piscicultura intensiva es prácticamente desconocida. Esta situación es debida: (i) al desconocimiento de numerosos aspectos de la biología de esos peces; (ii) a la existencia de técnicas perfeccionadas de piscicultura comercial de peces exóticos, las cuales son transplantadas y adaptadas en la región, juntamente con la importación de esos peces; (iii) hasta el momento el "método de hipofisación" está limitado a las estaciones de piscicultura del gobierno del Brasil.

Juzgamos necesaria la discusión de las recomendaciones presentadas a seguir: (i) los servicios de pesca y piscicultura en América del Sur y Central deben trabajar en colaboración con las universidades, otorgando becas y medios materiales a los investigadores universitarios, para el estudio de la reproducción de los peces nativos o indígenas en naturaleza y en cautiverio; (ii) una vez establecidos los principios de tal reproducción en cautiverio y de la piscicultura comercial de esos peces, los servicios de pesca y piscicultura deberán promover la piscicultura rural, por medio de los servicios de extensión agrícola; (iii) caso aprobadas las dos primeras recomendaciones, sería indicado tuvieran el apoyo de la FAO, por medio de sus oficinas en América del Sur y Central.

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IV/E-1

A REPRODUCTION CONTROL FACTOR IN THE CYPRINID FISH, BRACHYDANIO RERIO

by

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Abstract

A reproduction control factor is a possible solution to fish population regulation in ponds. A factor which significantly reduced spawning of *Brachydanio rerio* was found in water conditioned by *B. rerio* for 60 days or more at a stocking rate of 26.9 g in 40 l. This stocking rate is equivalent to 31 kg/are in a pond 0.5 m deep. It was not found in water with stocking rates up to 20 g of fish in 40 l, or in water conditioned for up to 47 days by 30 g of fish in 40 l. The factor apparently affects spawning activity rather than maturation of gametes.

Chemical analyses indicated a possible relationship between high concentrations of ammonia and carbon dioxide and reduced spawning.

UN FACTEUR LIMITATIF DE LA REPRODUCTION CHEZ LES CYPRINIDE, BRACHYDANIO RERIO

Résumé

Un facteur limitant la reproduction pourrait constituer une solution au problème du contrôle des effectifs de poissons en étang. Un facteur qui réduit sensiblement le frai de Brachydanio rerio a été constaté dans des eaux où celui-ci avait séjourné pendant 60 jours ou davantage, avec une charge de 26,9 g de poisson par 40 l d'eau. Cette densité de peuplement correspond à 31 kg/are dans un étang de 0,5 m de profondeur. La présence de ce facteur n'a pas été décelé dans de l'eau changée jusquà 20 g de poisson par 40 l ou dans de l'eau changée à 30 g de poisson par 40 l pendant une période allant jusqu'à 47 jours. Ce facteur semble influer sur l'activité reproductrice plutôt que sur la maturation des gamètes.

Les analyses chimiques font ressortir la possibilité d'un rapport entre de hautes concentrations d'ammoniac et d'acide carbonique et une diminution des activités reproductrices.

UN FACTOR LIMITADOR DE LA REPRODUCCION EN EL CIPRINIDO BRACHYDANIO RERIO

Extracto

Un factor de limitación de la reproducción es una posible solución para la regularización de las poblaciones ícticas en los estanques. Un factor que redujo el desove en forma considerable de Brachydanio rerio se encontró en agua condicionada por B. rerio durante 60 días o más en una proporción de 26,9 gramos en 40 litros. Esta densidad de población equivale a 31 kg por área en un estanque de 0,5 m de profundidad. No se observó en aguas con densidades de población hasta de 20 gr de peces en 40 litros o en aguas condicionadas hasta 47 días con 30 g de peces en 40 litros. El factor evidentemente influye en la actividad de desove y no en la maduración de los gametos.

Los análisis clínicos señalaron una posible relación entre las elevadas concentraciones de amoníaco y anhidrido carbónico y la reducción del desove.

1 INTRODUCTION

Control of fish populations in ponds is basic to efficient fish cultural methods. The problem of population control is usually one of controlling overcrowding. This can be done by introducing a predator or by curtailing reproduction. The use of a reproduction control factor is a possible solution.

The presence of a reproduction control factor in crowded populations has been demonstrated for several species of fish (Chaudhuri, 1955; Rose, 1959; Swingle, 1954; 1956a; 1956b; 1957a; 1957b). The reproduction control factor must be studied more intensively if it is to be utilized in management of fish populations.

The investigation reported in this paper was undertaken to study repression of reproduction of the cyprinid, *Brachydanio rerio* (Hamilton-Buchanan), including the chemical nature of the repressive factor, the population densities, and the lengths of time required to produce repression.

2 MATERIALS AND METHODS

2.1 Fish

B. rerio is widely used as an ornamental fish. The fish used in this investigation were purchased from a tropical fish dealer or raised in the laboratory.

They were fed a variety of dry commercial tropical fish feeds supplemented with live and frozen zooplankton, live sludge worms, chopped earthworms, and fresh fish eggs when available.

Brood fish were held separate by sex at densities of 20 to 70 per aquarium. The holding tanks were cleaned by water changes, filtration through glass wool and charcoal, and by use of snails. When the water was changed, usually it was partly replaced with water that had been aerated for at least 24 hours in a clean aquarium.

2.2 Equipment

The fish were held in aquaria containing approximately 40 l of water that was aerated constantly through air stones. Glass covers were used to reduce evaporation and to prevent fish from jumping out. City water dechlorinated by charcoal filtration was used.

All experiments were conducted at a water temperature of about 23°C. Aquaria were illuminated by fluorescent lights suspended 25 to 28 cm above their covers. Lights were turned on for 12 hours in each 24 hour period.

2.3 Spawning tests

Spawning tests were conducted in circular glass battery jars 14 cm in diameter containing 1.5 l of water, producing a depth of about 9.5 cm. A wire screen that allowed the eggs to fall through was fitted over the bottom of the jar to keep adults from eating the eggs. Jars were covered to reduce evaporation of water and to prevent fish from jumping out. An artificial spawning mat was used, consisting of narrow strips of green plastic fastened between two twisted wires somewhat like a limp bottle brush. A 12 cm piece in each spawning tank was readily accepted as a spawning substrate. Each spawning tank was aerated through an air stone.

A test consisted of stocking two pairs of *B. rerio* in a spawning tank containing the water being tested. The tank was then observed periodically for eggs. The observation period was usually 72 hours. After the test the water was returned to the aquarium from which it had been taken to maintain the volume without dilution.

2.4 Water analysis

The pH was measured with a Beckman Zeromatic pH meter with glass electrodes. Carbon dioxide, carbonate, and bicarbonate were determined by methods slightly modified from those given by Welch (1948). Ammonia, nitrate, and nitrite were determined colorimetrically by slight modifications of methods given by the American Public Health Association (1955).

2.5 Statistical methods

Data from preliminary tests were analyzed by the method of exact probabilities in 2 X 2 tables (page 379, Steel and Torrie, 1960). A rank sum test (Wilcoxon, 1949) was used for 1963 spawning data because this procedure does not require the assumption of a normal distribution of the data. Linear regression was used to test the relation of chemical data to spawning success in the 1963 tests.

2.6 Conditioned water

Water conditioned by B. rerio was produced by stocking known weights of fish in 40 l of water in aquaria. The aquaria were cleaned as needed by filtering the water through cotton or glass wool. Dead fish were not replaced in preliminary tests, but were replaced in the 1963 experiments with fish of approximately the same size to maintain the weight of fish in the aquaria. The conditioning fish were fed only a variety of dry tropical fish feeds.

3 PRELIMINARY EXPERIMENTS

3.1 Procedure

Three aquaria were stocked between October 1961 and September 1962. Stocking dates and rates are given in Table I. After various lengths of time (Table I), the water was used in spawning tests. Spawning tanks with dechlorinated, aerated tap water were set up as controls in conjunction with all of the tests except the 47-day test of water from Aquarium 9.

3.2 Results

The results of these preliminary tests are presented in Table I. The critical density appears to be between 17.1 and 26.9 g and the critical time between 47 and 60 days. Further tests to confirm these results and to relate water chemistry to repression were conducted in 1963.

4 EXPERIMENTS IN 1963

4.1 Procedure

Three aquaria containing 40 l of water were stocked with B. rerio on 16 January 1963. Aquarium 11 received 10 g; Aquarium 12, 20 g; and Aquarium 13, 30 g of fish. Aquarium 14 was set up without fish as a control.

Water from each aquarium was analysed for pH, carbon dioxide, bicarbonate, carbonate, ammonia, nitrate and nitrite at intervals from 30 January through 10 April. After 10 April only the pH was measured; and it was occasionally adjusted upward with calcium oxide to approximately pH 7. Four spawning tests were performed periodically in the water from each of the four aquaria. The tests were generally conducted at two-week intervals.

4.2 Results

Results of these spawning tests are given in Table II. The overall data showed no significant difference between number of spawns in the four different waters. However, spawning in the water from Aquarium 13 (30 g of fish) was significantly reduced ($p < 0.05$)

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Table I

Spawning success of *B. rerio* in water conditioned by *B. rerio* in preliminary tests

Water source	Stocking date	Stocking rate g/40 l	Days since stocking	No. of tests	No. of spawns
Aq. 8	5 Oct., 1961	17.1	60	3	3
			117	2	1
Aq. 9	8 Mar., 1962	26.9	32	3	3
			47	1	1
			60	4	0
Aq. 10	10 Sept., 1962	29.5	63	5	0
			77	5	0
Tap water	-	-	-	18	10

Table II

Spawning success of *B. rerio* in water conditioned by *B. rerio* in 1963

Date of test	Days after stocking	Number of spawns in four spawning tests			
		Control water	Grams of fish per aquarium		
			10	20	30
Feb. 4	19	4	2	1	2
Feb. 18	33	4	4	4	4
March 4	47	3	4	4	4
March 18	61	2	4	2	1
March 26	69	3	no test	3	2
April 9	83	4	3	4	2
April 22	96	2	2	1	1
May 14	118	4	4	3	3

when compared with spawning in water from Aquarium 14 (no fish).

When the data were divided into four parts on the basis of stocking rates (more or less than 25 g) and length of time since stocking (more or less than 60 days) as indicated by the preliminary tests, the following relationships became evident. Spawning in water stocked with more than 25 g of fish for more than 60 days was significantly reduced when compared with (i) all other stocking rates and lengths of time after stocking ($p < 0.01$), (ii) the same stocking rate for less than 60 days ($p < 0.05$), or (iii) less than 25 g stocking rate for the same length of time ($p < 0.05$). These results confirm the presence of a critical time and stocking density found in the preliminary experiments.

There was no relationship between spawning success in the test tanks and the results of the chemical analyses in Aquaria 11 and 12. The data from Aquarium 12 (30 g of fish) suggest that high concentrations of ammonia (up to 10.4 ppm) and carbon dioxide (up to 20.4 ppm) are related to low spawning success. However, these relationships are not significant statistically ($p > 0.10$).

5 TESTS OF CONDITIONED FISH

In all previous experiments, test fish were exposed to the conditioned water for the first time in the spawning tank. This method would not demonstrate a factor that required a long time to affect the fish. Thus, it was decided to test the fish that were conditioning the water. On 28 May, 131 days after stocking, spawning traps were put in Aquaria 11 (10 g of fish), 12 (20 g of fish), and 13 (30 g of fish). Fish spawned in all three aquaria within 72 hours. The pH was measured in all three aquaria 48 hours after addition of spawning traps. The pH of Aquarium 11 was about 7.2 throughout the entire test, but the pH values of Aquaria 12 and 13 were 5.4 and 4.4, respectively, and were adjusted upward to about 6.4 and 6.5, respectively. On 1 July, 166 days after stocking, a spawning trap was put in Aquarium 13 and observed until 11 July. Measurements of pH were also made during this period, and pH was adjusted upward toward 7 on 9 July. On 11 July, all the fish were removed from Aquarium 13 and placed in fresh water in Aquarium 15. At the same time Aquarium 13 was stocked with 12 pairs of new fish. Spawning traps were placed in both aquaria. The spawning trap was removed from Aquarium 15 two days later and was replaced on 16 July. The experiment was terminated on 17 July.

Between 1 July and 11 July, 1963, no spawnings were recorded in Aquarium 13. However, when these fish were transferred to fresh water in Aquarium 15, they spawned the next two mornings and again 16 July when the spawning trap was replaced, thus demonstrating that the fish were still in spawning condition.

The new fish introduced into the conditioned water of Aquarium 13, spawned only 12 eggs 113 hours after the spawning trap was added. They spawned 5 more eggs in the next 23 hours. This was a definite delay in spawning and a marked reduction in the amount of spawning as compared with that expected from these fish in fresh water.

6 DISCUSSION

These results show that B. rerio produces a factor that represses reproduction. The factor appears to be a substance secreted by the fish that requires a minimum time (60 days) to build up to an effective strength. Apparently the material dissipates in the water and a minimum weight of fish is required to maintain the concentration. The minimum weight of 25 g/40 l corresponds to a stocking weight of about 31 kg/are in a pond 0.5 m deep.

The reproduction control factor apparently does not affect the development of the gametes but only the act of spawning. It affects fish immediately when they are exposed to it, but the effect wears off rapidly when the fish are removed from it.

7 CONCLUSIONS

Water conditioned by 26.9 g or more of B. rerio for at least 60 days significantly repressed spawning of B. rerio. Lower weights of fish or shorter times did not produce significant reduction of spawning success when compared with that in fresh water. The effect is apparently on spawning activity, not on the maturation of gametes.

In most Aquaria there was no relation between the results of chemical analyses and spawning results. However, in one aquarium the data suggested that high concentrations of ammonia and carbon dioxide were related to low spawning success, but the relationships were not significant ($p > 0.10$).

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STUDIES ON THE BREEDING OF CARP (CYPRINUS CARPIO) AT THE EXPERIMENTAL POND FARMS OF THE POLISH ACADEMY OF SCIENCES IN SOUTHERN SILESIA, POLAND

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IV/E-2

STUDIES ON THE BREEDING OF CARP (*CYPRINUS CARPIO*) AT THE EXPERIMENTAL POND FARMS OF THE POLISH ACADEMY OF SCIENCES IN SOUTHERN SILESIA, POLAND

Abstract

Studies were made of the systematics of the carp and its breeding in ponds. Anatomical studies were also made on age classes from fry to the tenth year. A new variety of carps - the blue carps: *Cyprinus carpio* variety *cerulea* - was bred. All studied populations were sib populations reared separately in different ponds. The variability studies were made with a biometric scheme of five features, and led to the conclusion that there exists in carp populations a phenomenon of stabilizing effect on variability which consists of an initial high relative variability diminishing during the first three years of growth and then stabilizing on certain levels which are characteristic for the feature investigated. Problems of selection of carp spawners on the basis of the occurrence of the stabilizing effect are discussed and a method of selection of spawners on this basis is proposed. Practical examples of this method are given. The problem of compensation growth in carp populations is discussed. Sex ratio in carp populations was studied and it was found that in natural carp populations it is according to the biological law of 1:1, and the selection for weight shifts this ratio towards females.

ETUDES SUR L'ELEVAGE DE LA CARPE (*CYPRINUS CARPIO*) DANS LES EXPLOITATIONS PISCICOLES EXPERIMENTALES DE L'ACADEMIE DES SCIENCES DE POLOGNE EN SILESIE DU SUD (POLOGNE)

Résumé

Des études ont été faites sur la systématique de la carpe et sur son élevage en étang. Des études anatomiques ont également été menées sur les classes d'âge allant des alevins aux carpes de 10 ans. Une nouvelle variété de carpe, la carpe bleue, *Cyprinus carpio variété cerulea* a été créée. Toutes les populations étudiées étaient issues des mêmes parents et élevées séparément dans différents étangs. Les études de variabilité, effectuées avec un schéma biométrique comprenant cinq caractères, ont permis de conclure qu'il existe chez les populations de carpes un phénomène qui a un effet de stabilisation sur la variabilité: en effet, on constate au début une forte variabilité relative qui diminue au cours des trois premières années de croissance pour se stabiliser à certains niveaux qui sont caractéristiques du caractères étudié. L'auteur examine les problèmes de la sélection de reproducteurs en fonction de l'apparition de cet effet de stabilisation et propose une méthode de sélection des reproducteurs sur cette base. Il donne des exemples pratiques de cette méthode. Le problème de compensation de la croissance pendant le developpement chez les populations de carpes est examiné. L'étude du rapport des sexes a montré que dans des populations naturelles de carpes il correspond à la loi biologique de 1 : 1, et que la sélection en vue du poids modifie ce rapport en faveur des femelles.

IV/E-2

ESTUDIOS SOBRE LA CRIA DE CARPAS (CYPRINUS CARPIO) EN LOS ESTANQUES PISCICOLAS EXPERIMENTALES DE LA ACADEMIA POLACA DE CIENCIAS EN SILESIA MERIDIONAL, POLONIA

Extracto

Se efectuaron estudios de la sistemática de la carpa y de su cría en estanques. Igualmente se hicieron estudios anatómicos sobre clases de edad, desde alevines hasta el décimo año. Se crió una nueva variedad de carpa: la carpa azul, (*Cyprinus carpio* var. *cerulea*). Todas las poblaciones estudiadas eran poblaciones de hermanos y hermanas criados separadamente en distintos estanques. Se efectuaron estudios de variabilidad con un plan biométrico de cinco características que llevó a la conclusión de que existe en las poblaciones de carpas un fenómeno de efecto estabilizador sobre la variabilidad consistente en una variabilidad inicial relativamente elevada que disminuye durante los tres primeros años de crecimiento y qu, luego, se estabiliza a ciertos niveles que son característicos para los aspectos investigados. Se examinan los problemas de la selección de hembras carpas para freza sobre la base de la existencia del efecto estabilizador y se propone sobre dicha base un método de selección de las hembras en desove. Se citan ejemplos prácticos de este método. Se discute el problema del crecimiento de compensación en poblaciones de carpas. Se estudió la proporción de sexos en las poblaciones de carpas, observándose que en las poblaciones naturales de dicha especie corresponde tal proporción a la ley biológica 1:1 y la selección para peso hace aumentar esta relación a favor de las hembras.

1 INTRODUCTION

The subject of this paper is the selection of carp (Cyprinus carpio) stocks for spawners to improve or maintain the productive quality of carp stocks. Staff (1925) drew attention to the need for genetic investigations based on fish measurements, biometrics and genetics of Polish carp. Such studies have been made from 1953 to 1963 at the experimental farms of the Laboratory of Water Biology under the guidance of Professor K. Starmach.

Poland has an old tradition of carp breeding. Carp culture was introduced by the monasteries in the thirteenth century and was well developed by the sixteenth century (Chmielewski, 1965). The "Polish" race of carp originated in Southern Silesia in the latter part of the nineteenth century. This race is characterized by fast weight increase and a good shape. It was developed in the Upper Vistula region, where the area under fish culture was two or three times more extensive a few centuries ago than it is now.

We cannot today speak of pure races of carp, since fish farmers have crossed local races with imported spawners in the last 85 years. Nevertheless pure strains of Polish carp probably exist in the Upper Vistula region, since this was an export and not an import area. During the second world war, the people living there in many instances saved carp stocks so that carp culture could start anew. Unfortunately the best Polish strain, known as the Osiek strain, to produce which took the lifetime of two human generations, was lost. But its blood is preserved in several strains now reared at the experimental farms of the Polish Academy of Sciences.

2 STUDIES ON THE VARIABILITY OF CARP POPULATIONS

2.1 Methods used

2.1.1 Schemes of measurements

Before beginning the study of variability in a carp population we were confronted with the problem which features should be measured. Several old schemes existed such as the Berg scheme (Berg, 1949), Starmach's scheme used in systematic investigations, Naumann's scheme (Naumann, 1927) and others. Since our study of variability was intended primarily for breeding purposes and not for studies in systematics, the criterion used in choosing features that should be measured needed to be correlated with body weight. This problem was solved statistically by applying multiple correlation analysis using special algebraic methods called cracovian methods in the multiple calculus; these greatly facilitated the statistical analysis (Wlodek, 1959a). Out of these statistical studies there emerged a scheme of measurements which was called the "breeding scheme." This was used subsequently at the farms (Wlodek, 1961). It consisted of five features: body weight, body length (longitudo corporis), height (maxima altitudo), width (latitudo corporis) and head length (longitudo capitis). Fishes were measured for the first time at the transfer from the first to the second fry ponds. As this occurs under our climatic conditions and in our system of production in the first days of July, we call those fry which are generally one month old "July fry." Then the carp were measured every autumn just after removal from ponds and every spring before stocking. Representative random samples of the fry population were measured because the numbers of fishes are as a rule very great. The selected populations were then usually measured as 100 percent samples, the number of fishes in these populations being in the hundreds and not in the tens of thousands as in the case of the fry populations. The selected populations were tagged so that individual biometric records of a fish could be kept throughout its life. They were also photographed so that they could be distinguished in case the tags were lost. In this way a catalogue of spawners was made. Stegman (1965a) considers the correlation analysis as useful in breeding.

2.1.2 Breeding methods

2.1.2.1 Sib-populations

The variability of carp sib-populations, derived from crossings of one male with one female were investigated. This is usually not practised here in pond management where spawn ponds are generally stocked with one female and two males (one large and one small). The one-couple pairing gave assurance of parentage, because when working on a normal non-sib-population one is never certain from which parent a fish comes. Also the genotypical part of variability may be greatly influenced by this type of crossing. Such sib families were named after Starmach "families." (Starmach, 1955), Moav and Wohlfarth (1963) stress the point that the sib tests are a major criterion for the estimation of breeding values.

2.1.2.2 Separate rearing

The sib-populations were always reared separately from other populations. This was especially important in young stages of life when mixing of fry may occur on farms. They were also reared as separate age classes to be sure of their age.

2.1.2.3 Times of spawns

Carp generally spawn in the Upper Vistula region between 25 May and 5 June, therefore all investigated sib populations were of the same average age. Carp spawn in such a way that the individuals in a population are always exactly the same age. This ensures that there are no "sub-populations" forming which might hamper the comparison of results because of the uncertain age of a young population.

2.1.2.4 Environmental conditions

The populations investigated were always reared together in one pond. In this way the environmental conditions for a population were the same for all the investigated fishes. Therefore one could compare the growth between individuals and avoid the difficulties in investigations pointed out by Backiel and Bontemps (1958). This point is stressed by Schäperclaus (1961) as an essential condition for breeding spawners.

2.1.3 Statistical methods

In the initial studies on the schemes of measurements I used multiple correlation and regression analysis. Partial regression and correlation coefficients were calculated as well as other multiple statistics needed in this type of study. The cracovian algebraic calculus facilitated the technique of calculations which may sometimes be very cumbersome, especially if the number of variables in the study is great (Wlodek, 1954). A comparative study of methods was made which proved that from the operational point of view the cracovian methods are best for multiple analyses (Wlodek, 1959e). For the subsequent variability studies only a basic statistical analysis was applied, i.e. means, standard deviations and coefficients of variation were calculated. The basic conclusions on the development of variability in a carp population were derived from the coefficients of variation, that is on relative variability in time.

2.2 Stabilizing effect of variability

2.2.1 In sib-populations

Observing the relative variability of carp populations there was always a certain pattern of the development in time of variability; the initial high relative variability always dropped during the second and third year of growth, and afterwards stabilized at certain levels characteristic for the feature investigated (Wlodek, 1967b). This is shown for the principal feature of weight in Fig. 1. Fig. 1 was drawn on the basis of all the data gathered during ten years of variability studies at the experimental farms "Ochaby." A total of 234 ponds were investigated and 23,391 fish measured. In this number there were 1,528 adult carp from K_5 stage inclusive. As may be seen from Fig. 1 the greatest drop in variability can be observed during the two first years, but the decrease continues in the third year. Later the level of variability is stabilized around a mean of 12 percent (the "stabilization level"). One may see from this figure that the range of variability was greater in young populations (about 30 percent) than in older ones. The greatest encountered variability of July fry in sib-populations was about 55 percent, the lowest about 23 percent and the average variability 37 percent. The stabilization of variability in a carp population can be regarded as accomplished after the three first years of growth. Mišik (1958) when studying the biometric conditions of the wild Danubian carp (Cyprinus carpio carpio) came to the conclusion that the plastic features of this carp are stabilized from the third year of growth. The morphometric features in my studies stabilized at a 4 percent to 7 percent level, according to the feature, also from the third year of life. Backiel (1954) observed the diminution of variability and equalization of populations in respect to caudal length of carp fry in Central Poland.

In our climate and region (upper Vistula basin) the stabilized variability did not show very important fluctuations in either weight or morphometric features. The changing environmental conditions may induce fluctuations of the coefficients of variation, but never did I find very substantial changes. The variability never returned to levels encountered in the first or second years of growth. Knowledge of this pattern of development of variability can be of help in the selection of spawners (see Section 7.3).

2.2.2 In non-sib-populations

All conclusions about the occurrence of the stabilizing effect of variability pertain strictly speaking only to sib-populations as I found it in those populations. Nevertheless there are many indications in the literature which allow us to extend the conclusions to non-sib-populations. Golovinskaja (1960) stresses the point that populations of future spawners reared at the Zagorsk experimental farm equalized their growth in the course of development and the experiment she made shows this clearly, but she did not say whether she worked on sib-populations. Naumann (1927) gives data on relative variability in carp populations which prove the decrease in relative variability during the first year of growth in different geographical races of carp, i.e. also in non-sib-populations.

2.2.3 Stabilization of variability depending on race and environmental conditions

The data which Naumann (1927) gave on the variability of carp populations may indicate that there exist different variability levels, according to the race of a population. He investigated two populations, one of them was of Lusatian origin, the second was a cross between the Galician carp and Czech carp. The Lusatian race showed smaller fluctuations in variability, whereas the cross showed a very heavy drop of initial variability. Kirpitschnikov (1961), Anwand (1961), Polakov (1958) and Naumann for Lusatian carp (1927) give data on K_1 which do not show great differences (Table II).

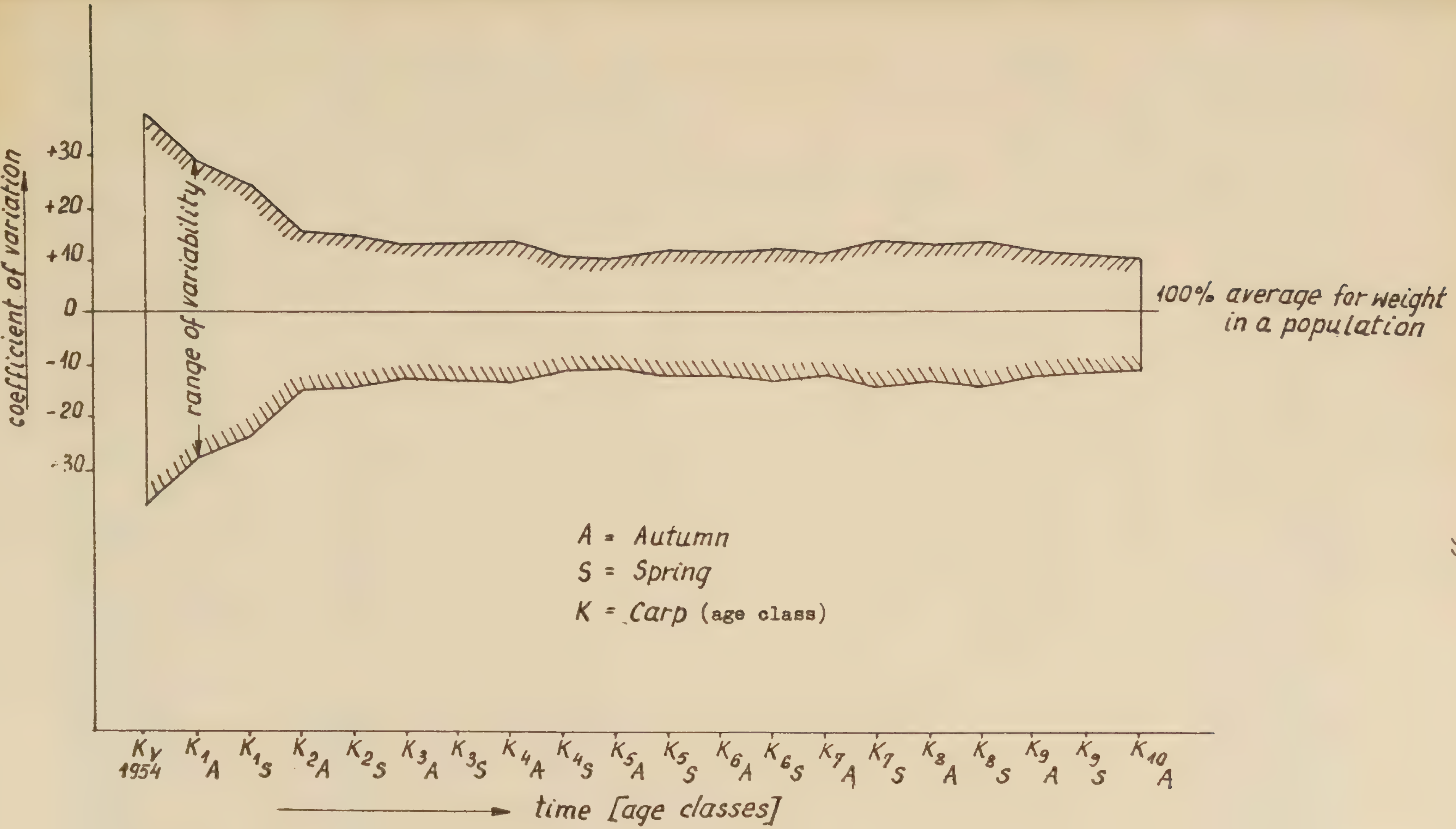

Fig. 1 Stabilizing tendency of weight variability in carp sib-populations during growth (experimental farms "Ochaby" Southern Silesia, Poland)

Table I

Variability coefficients of weight for different races of carp

	K_1	K_2	K_3	K_4
Lusatian	24.0	17.5	13.1	20.4
Galician x Czech	61.6	28.7	14.7	12.5
Polish sibs	28.3	15.0	12.5	13.5

Table II

Variability coefficients of weight of different populations of carp at K_1 studied by different authors

Naumann (1927), for Lusatians		24.0
" for Galician x Czech		61.6
Kirpitschnikov (1961), for the north of U.S.S.R.	scaled	33.5
	mirror	34.7
Anwand (1961), for Lusatia (mirror)		30.5
Polakov (1958), for central U.S.S.R.		26.5
Wlodek for Polish sibs (upper Vistula basin)		28.3

The greatest relative variability was shown by carp from a cross. This might have been due to different factors. The variability was twice as great as that found for all other populations (Table II) which was about 30 percent. Therefore one may infer that this was due to the racial inter-crossing than to different genotypical components of variability or geographical differences. Polakov (1958) showed that there is an interdependence between the mean weight of a population of fry at K_1 and the average relative variability. The correlation coefficient of this relation calculated from Polakov's data was + 0.64. As the mean weight is in turn dependent on the crowding of a pond, one may infer from Polakov's data that the relative variability is primarily dependent on the crowding of a pond. Stegman (1965b) investigated the influence of different feeding conditions on K_2 carps. He observed that the variability rose as greater individual weight was reached.

Those two main factors, the genetical and environmental, both have a great influence on the degree of variability. The environmental factors seem to have most effect before the population has reached maturity.

2.2.4 In other fish species

In other fresh-water fish populations the decrease of variability with age was observed by Backiel (1958), from Entz (1952) in data for bleak (Alburnus alburnus) in the Hungarian lake Balaton and in the crucian carp (Carassius carassius), and by Skóra (1961) from ponds at the experimental farms "Ochaby." Skóra (1964) also found this in the tench (Tinca tinca) living in an artificial lake. Balon (1960) made aquarium experiments with the development of larval stages under unfavourable feeding conditions in the wild Danube carp (Cyprinus carpio carpio) the roach from the Danube (Rutilus rutilus carpathorussicus) and with Abramis ballerus also from the Danube. He found that in these species there exists an equalizing tendency of growth. According to a report from the Tropical Fish Culture Research Institute at Malacca it seems that the stabilizing effect also occurs with tropical fresh-water fishes (Malacca, 1961). Skóra and Wlodek (1966) also found a decrease of variability with time in different age classes of gudgeons (Gobio gobio) in the Sola river (right confluent of the Upper Vistula). The work of Zamachajev (1964) gives many examples of compensation growth in fresh-water as well as salt-water fish species. Smith (1956, after Zamachajev) considers that compensation growth in fishes is probably a general phenomenon.

3 STUDIES ON SYSTEMATICS OF CYPRINUS CARPIO

The systematics of the Cyprinus carpio from the experimental farms "Ochaby" were studied using the scheme of measurements by Starmach and Rosol (1961). The anatomic features of this scheme are given in the works of Wlodek (1959b, 1964b, 1966). The big Starmach scheme uses 47 features grouped as follows:

(i) length measurements (8)
(ii) fin length measurements (9)
(iii) body proportions (5)
(iv) height measurements (4)
(v) width measurements (2)
(vi) circumference (1)
(vii) numbers of fin rays (4)
(viii) swim-bladder features (4)
(ix) number of vertebrae (1)
(x) body weight, and the weight of its main parts (5)
(xi) weights of gonads and entrails (4)

The anatomical investigations are described in section 6. The morphological features (groups 1-7) were studied both in proportions of the body length (longitudo corporis) and by basic statistical analysis, that is means and variability were calculated (Wlodek, 1959a; 1964a). The investigations were made on four age classes. They proved that the stocks marketed at the experimental farms are of Polish origin. The decrease in variability was already observed, showing that this diminution can be very sharp in a population. Certain features did not show changes with time. These were the number of fin rays, the number of vertebrae and certain proportions. These are therefore diagnostic features. The fin rays averaged 21.6 dorsal rays, 6.4 anal rays, 15.4 pectoral and 8.4 pelvic rays. The vertebrae always numbered 37. The number of fin rays was similar to that quoted in literature, Bauch (1955), Urbanowicz (1956), Kirpitschnikov (1958). Kirpitschnikov (1958) considers the number of rays in the dorsal fin as an especially important feature. Some morphological features maintained their stability in proportion to the body length during the period investigated (the first four years) while others behaved in an unstable manner, as stable features may be reckoned:

longitudo pinnae dorsalis
longitudo pinnae ventralis
summa longitudo pinnae analis
longitudo lobi inferioris pinnae caudalis
longitudo radii medii pinnae caudalis

The variability of features decreased up to the stage K_3. No pronounced differences between the sexes were observed in average values of morphological features. Anatomical investigations on mature carps proved that there are differences between young and adult fish; therefore one has to be careful in inferring from the features measured in young stages the probable features of the adults.

4 GROWTH OF CARPS

4.1 Growth of spawners and variability

The individual growth of spawners was observed in many sib-populations at the experimental farms "Ochaby" for many consecutive years. Two populations were observed uninterruptedly for ten years. This growth is illustrated in Fig. 2. The curve of growth and the accompanying curves of variability were constructed as indices based on respective general means. The growth in young stages, when fishes were not individually tagged, was taken for the same populations. The data pertain to averages derived from observation of individual adult fish. One sees clearly that the growth curve breaks regularly each winter. This indicates the loss in condition of fish during winter. The standard deviation curve follows the growth curve and also breaks its upward tendency during each winter. This confirms my earlier observation on wintering carp (Wlodek, 1959d).

Only once during the whole investigation did the growth curve break its upward trend; this was in the eighth year, which coincided with the bad growing season (1962) caused by climatic factors. It is interesting to note that the standard deviation curve follows closely the growth curve, but we observe only once a discrepancy between them, this is just in the eighth year of growth, when the unfavourable climatic conditions induced greater absolute variability in the fish. In the next year this curve returned to its previous trend. The correlation coefficient between those two curves proved to be nearly functional (0.99). The curve for relative variability shows clearly the initial heavy drop. After the drop the curve shows a level of variability around an average which can be called the stabilization level. The changes during the stabilized period are probably induced by the changing environmental conditions from pond to pond and from year to year. There was never a substantial change in relative variability, comparable to the initial decrease. The calculations of the three curves were based on their respective total means.

We see from Fig. 2 that the curve of relative variability does not follow the upward trend of the growth curve. It diminishes up to the end of the third growing season. The diminution during the last period was not so sharp as in the two previous ones. This proves that homogenous (sib) populations grow more or less proportionally after they have accomplished the decrease of variability in the first three years. The calculation of indices was based on 23,391 fish from 234 ponds from 1954 to 1963.

4.2 The initial weight of fry for the production of future spawners

The possibility that an individual may not be congenitally(phenotypically) favourable but at the same time may be genotypically favourable (see section 7.3.3) leads to the conclusion that the initial weight of fry for populations of spawners may be not so important for the selection of future spawners as it is sometimes considered. This problem may have important economic implications and was perhaps the real reason why Walter (1934) arrived at the same conclusion. Golovinskaja (1960) recently came to the same conclusion too, on the grounds of her experiments at the Zagorsk experimental farms. Data gathered during the growing of future spawners at the experimental farms "Ochaby" prove the same.

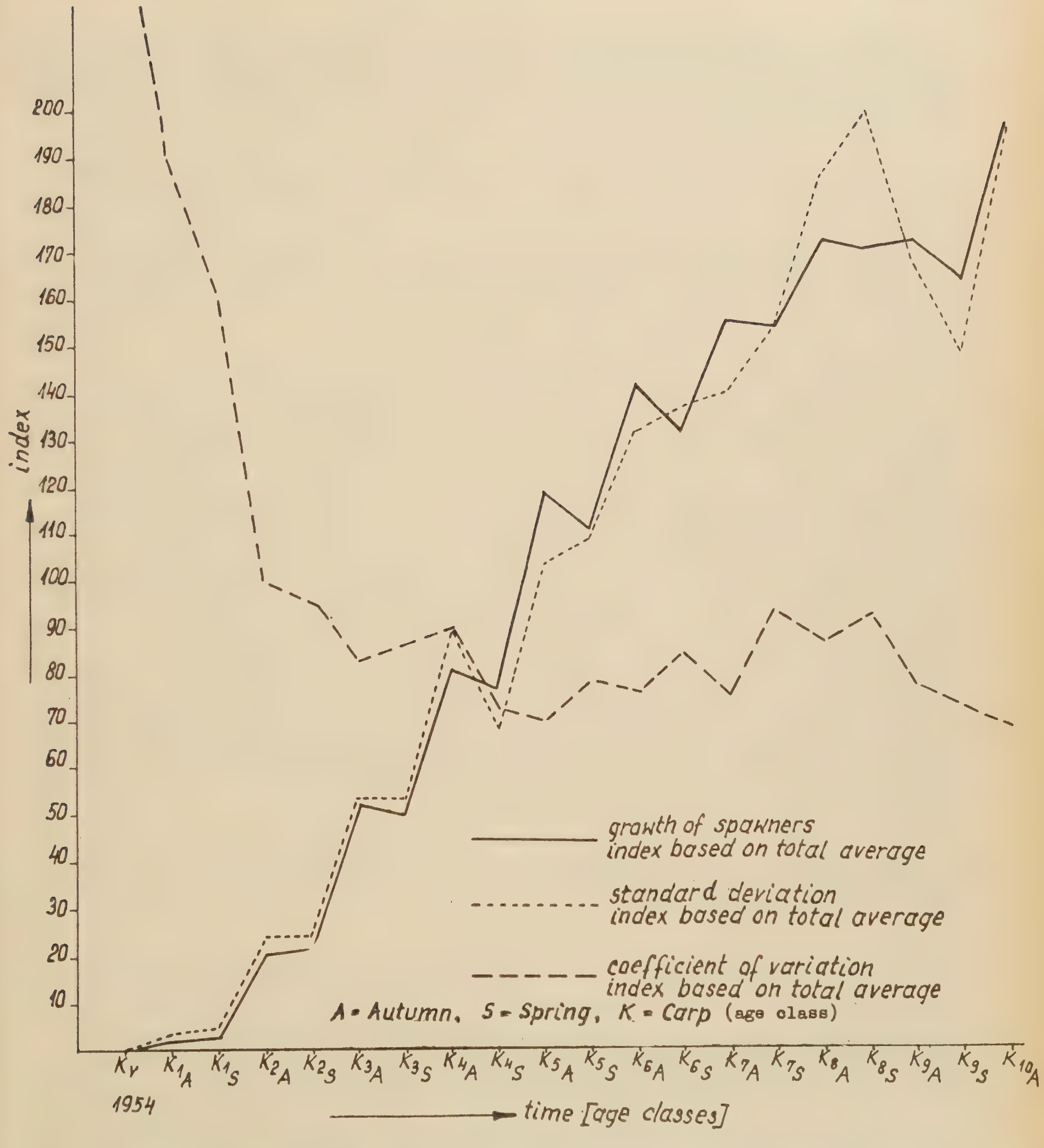

Fig. 2 Growth of carp and variability (experimental farms "Ochaby" Southern Silesia, Poland - 1954-1963)

Spawners, whether large or small, reached in the fourth year of growth, despite their initial weight, practically the same weight. So from the point of view of weight which a spawner population reaches at its maturity, the initial weight is not important. This appears to be due to the stabilizing effect and the ensuing compensation growth in carp populations.

A high initial weight may be advisable on other grounds, for instance on health grounds. Personally I think it is better to have spawners of large initial weight. We may suppose that the bigger the fish are initially, the quicker they will pass the decrease of variability stage and the quicker will the variability stabilize. In this way we might reach a stabilization of variability for weight already in the K_3 stage, and the better genotypes might then be observed earlier by their better growth. Stegman (1965b) came to the same conclusion. He is of the opinion that for selection purposes it is better to have bigger fish.

4.3 Compensation growth in carp populations

The stabilizing effect of variability or equalizing tendency has, it seems, a direct connection with another phenomenon known in fisheries as the compensation growth. The stabilizing effect leads to the conclusion that the older a carp population is, the more uniform it is, the differences between the fish becoming less and less in the course of their development. The individual end-weights in autumn equalize about the mean for the population. This process can proceed from year to year, therefore the equalization from year to year in the population means may be greater. This phenomenon may be called the stabilizing effect of variability. In other fish species (herrings) the compensation growth was observed to occur during ten consecutive years (Zamachajev, 1964) but in carp this was accomplished in three years. The system of pond management in use at the farms may be responsible for this. The consecutive thinning of a population that was being transferred from pond to pond was the principal cause of the decrease of variability during the first three years of growth. Theoretically, a situation is possible in which the compensation and stabilization of variability could occur during the first year of growth only. The works of Polakov (1960) indicate how the crowding of a pond affects the variability of the first year of life of carps. Such a thinning of population would be very uneconomic in the usual productive system, and therefore the stabilization and ensuing compensation occurs during the first three years of growth.

When a population is building up, large fish do not grow as quickly as the smaller ones; in this way fish compensate the differences in weight between them over a period of time. The greatest differentiation is observed in a carp population at the earliest stages of life.

The primary differentiation in a carp population is due to congenital (phenotypical) factors (Zarnecki, 1958). There are also genetic factors which can be seen by better growth of certain individuals. Genetic differences in growth may be seen after the stabilized period of variability has been reached, i.e. after the population has achieved its compensation. The genotype then shows its influence on growth in those fish that did not compensate their growth as did the majority of their sibmates. The initial differences existing at the starting point of growth of a fish population are considered by some authors to continue to exist in the population (Zamachajev, 1964). I think that this is only partially true in respect of carp populations reared in ponds; only those phenotypically favoured fish continue to grow significantly better than the rest of the population if they also possess the genetic constitution for better growth. Those which were phenotypically favoured but have no inner genotypic advantage are subject to the equalization tendency within the population. There is also a possibility that of the fish not phenotypically favoured at the start of growth, the genotypically favoured might accelerate their growth during the decrease of variability period, and afterwards continue to grow significantly better. I think that this is the reason for the apparent failure of mass selection in carps discussed by Moav and Wohlfarth (1963). The mass selection favours big individuals, regardless of genotype. The selector chooses fish only on the basis of their phenotype. The majority of "jumpers" which are chosen in this way compensate their growth during the first three growing seasons (see section 7.2).

Recently Korotkevič (1965) studied the occurrence of compensation growth in carp populations reared in Ukraine. He is also of the opinion that compensation growth exists in carp populations during the second growing season. In a non-sib-population there may be a sharper decrease in variability in the first years of growth than in a sib-population. This may occur because in such a population there are many components of genetic variability due to different parents of the population. Those considerations pertain to carp populations reared in ponds in our moderate zone climate, but the comparative basis furnished by the work of Zamachajev (1964) suggests that compensation growth occurs also in other fish species in both fresh and salt waters.

5 SEX RATIO IN CARP POPULATIONS

In natural carp populations or where the transfer from pond to pond is a random practice, the sex ratio is in accordance with the general biological law: 1:1 (Wlodek, 1959c). However selection in a carp population changes this ratio leading to more females. Selection takes place early in the life of fish, in the first or second year of growth, when we cannot yet distinguish between sexes, and the selector chooses bigger fish without considering the sex. The males grow more slowly than the females. This difference in growth may be observed already in the third year of life. At the experimental farms in our region the females were on the average 0.3 kg heavier in the K_3 stage and 0.4 kg heavier in K_4. Stegman (1965c) did not find differences in increases in weight between sexes in K_3 stage - only in K_4 stage. I think that the reason for this is that there are strains in carp populations which ripen differently. This discrepancy in weight of sexes is augmented during the subsequent years, as was proved by later anatomical investigations (Wlodek, 1966). The selector when choosing the fishes involuntarily takes more females than males. The probability of choosing a bigger individual was calculated and was found to be two thirds for choosing a bigger fish. Therefore the selected populations of carp spawners represent biased populations as to the sex ratio. This is why the spawner populations lack males. Nevertheless, I have found some males which in their growth were equal to the average female growth, or even in some rare cases surpassed it. Such individuals are very valuable from the point of view of breeding and must be carefully chosen from the selected carp stocks. Stegman and Wolny (1962) also draw attention to the fact that carp spawner stocks lack in males.

6 INVESTIGATIONS OF ANATOMIC STRUCTURE

6.1 The influence of sex in anatomic structure

Investigations on the variability of various anatomic features were made on mature carp stocks at the experimental farms "Ochaby" and on non-mature populations from here as well as from other pond farms (Wlodek, 1959b; 1964b).

These investigations proved the existence of differences in growth between the sexes. The males grow more slowly than the females. This difference on the average equal in the K_5 stage to 0.8 kg rose and reached 1.7 kg in K_{10}. One must remember that all investigated populations were sib-populations and lived always during a season in the same environmental conditions, that is in one pond. The differences were therefore accentuated as appearing between brothers and sisters. This difference may be observed already in K_4 stage, that is in the year when the majority of carps in a population reaches maturity. In the system of four years of rearing it could have some economic importance.

The right gonad generally was heavier than the left one; this was especially accentuated in females, in 65 percent of which the right gonad was heavier. In males this phenomenon was not so sharply accentuated; 25 percent had gonads of equal weight and in the rest the difference was only 2 percent. Gonads were found to be heaviest in the seventh year in females and the eighth year in males. Therefore one can assume that the greatest number of offspring can be expected from these age classes (Wlodek, 1966).

6.2 Anatomic structure before and after maturity

These investigations proved that the relative anatomic composition of spawners appears to be more or less stable, whereas in maturing carp it changes. In mature carps we can observe differences according to the sex of spawners; the females were heavier, mainly due to increase in the relative weight of the gonads.

The relative weights of various parts of the body before and after maturity, and for mature males and females, are given in Table III.

Table III

A comparison of anatomic features before and after maturity
in carp (*Cyprinus carpio*)

	before			after		
	K_2	K_3	K_4	K_{5-10}	♂	♀
Body weight	100.0	100.0	100.0	100.0	100.0	100.0
Head weight	21.4	17.1	14.5	13.2	13.5	13.1
Trunk weight	61.3	66.1	65.4	63.4	66.6	61.8
Fin weight	2.2	2.1	2.1	1.9	1.9	1.8
Entrails weight	13.1	13.3	16.8	19.3	15.6	22.1
Number of fish studied	119	13	37	187	57	130

One can see from this Table that from the production standpoint it would be more economic to produce more males in a carp population, especially in a long system of rearing. The differences in growth between males and females are accentuated before they reach their ages of maturity. Therefore the difference in growth between the sexes can be of some importance in a long system of production.

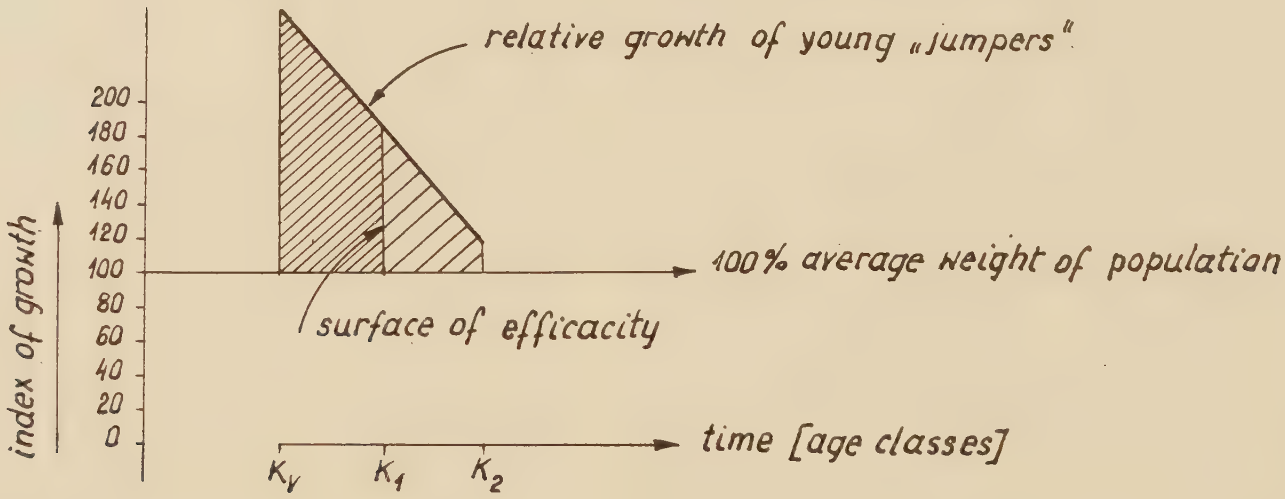

Fig. 3 Efficacity of sorting summer fry of carp

7 SELECTION OF CARP POPULATIONS

7.1 General considerations

The chief feature in selection of carp was body weight but exterior features were also considered. The scaliness was considered a very important factor. The carp of the mirror type were selected and those with a minimum of scales on the body surface, the frame type, were especially preferred. The health of the fish ranked also very high in the selection priority. The morphometric indices of body shape, calculated on the basis of measurements of morphometric features, were considered in selecting individuals but the main importance always lay in the weight factor, that is with the growth of fish during the first three years. Stegman (1965b) came to the conclusion that there is no correlation between the height index and the weight of fish in K_2 stage, which is most important because of the two seasons growing system prevailing now in Poland.

7.2 Early selections

The populations of carp reared in ponds show a more or less normal frequency curve (Zarnecki, 1964). The majority of fish live within the limits given by the frequency curve. But if we encounter in a class of fish more than can be expected on the grounds of the normality of the curve, then we may infer that there were causes other than mere chance for these fish to be found in given statistical limits. This reasoning is especially valid for classes where the occurrence of fish is rare, that is for the extreme wings of frequency distribution.

The youngest stages of the life of carp unaffected by man's selection, present from the statistical point of view large unbiased random samples. Therefore the July fry (summer fry) stage is best suited for frequency investigations. I investigated frequency curves from populations of July fry at the experimental farms "Ochaby" and found that over $(\bar{x} + ts)$ range was on the average 5.3 percent on the right side wing. Taking the normal curve into account there should have been only on one side of this curve 2.5 percent which means that I found twice as much as I expected. I think that one can assume for the rest of the fish that they had better genotypes of growth and that this was the cause for their being in this statistical class. We cannot distinguish from the exterior of fish which have the better genotype; we can only assign a probability for a fish in this statistical class to have a significantly (genotypically) better growth. In this class $(\bar{x} + ts)$ range which is most interesting from the breeding point of view, half of the fish could have been there by mere chance, and half whose presence could have been conditioned genotypically. Therefore the probability for a fish of better growth in this class was 0.5.

The investigations of July fry by Zarnecki et al. (1955) and Zarnecki and Czubak (1957) show that if we select a carp population so early, we may have an increase in production in a pond. On the basis of data given by Zarnecki et al. (1955) and Zarnecki and Czubak (1957) and my unpublished data I drew Fig. 3. This figure illustrates the effect of selection of larger fish from this early stage of life on productivity.

As can be seen from this figure the surface of effectiveness of the selection diminishes in the course of time. This occurs in my opinion in consequence of the existence of the stabilizing effect of variability in carp populations. In the two-year system of production which is in use in Poland the selection of July fry is effective. Fig. 3 brings out this clearly. At the end of the second growing season the difference between selected "jumpers" and the rest of the populations did not equalize. Therefore the farmer using selection procedures obtains an overweight. There is the problem whether during the third growing season the growth of a carp population compensates or not. If we consider that the stabilization effect of variability works for three years for the feature of weight, we may infer that the effectiveness of selection of July fry is economic also from the point of view of three seasons' system (see Fig. 3). The selection of July fry can give an average overweight of 15 percent at the end of the second growing season as illustrated. Stegman (1965d) confirms the good growth of "jumpers" class in K_2. The differences in weight of jumpers in his experiments in different pond farms and in different regions of Poland did not equalize during the second growing season. Only about 22 percent of big fry came out of the jumper class during the second growing season. The rest remained in the jumper class. The same held for the small fry, retarded in growth. I think therefore that one can, on those grounds, take for granted that early selection is also profitable from the economic point of view.

7.3 Selection on the basis of the stabilizing effect

7.3.1 The stabilization of variability and selection

Variability studies conducted at the experimental farms helped greatly to establish a selection method for spawners. The problem that always worries the breeder is how to distinguish the better genotype for growth by means of exterior inspection of an animal, here of a fish. The only certain method is that which compares the growth of offspring of two pairs of spawners in exactly the same environmental conditions, that is in the same pond. But if we have a great number of spawners or future spawners (selects), which is, or should be, the case in pond farms, we do not usually have a sufficient number of ponds to compare the offspring. I overcame this difficulty by comparing the growth of individual spawners over a time period with the variability range of the population of spawners from which the fish were desired.

Selecting on the basis of the stabilizing effect and using the catalogue of spawners (see 7.4) greatly facilitated the process of selection as one can consider a fish in advance of its removal from the pond, its morphometric indices of body shape, scaliness and principal features of growth as a total index of value of the fish. The final decision on the future of a select or spawner will always be taken after visual inspection after the removal of fish from a pond, but a list of spawners that should be taken for further reproduction facilitates the selection and helps to eliminate mistakes in choosing fish, which are inevitable if the number of fish to be selected is large. We can give then more weight to the health of the fish. If we can distinguish individual fish and have a record of their measurements, we can compare the growth of the individual with the pattern of variability for the whole population. On this basis a method of selection of spawners for weight was proposed by the author (Wlodek, 1967a). The majority of fish grow within the variability range, that is, within the limits given by $(\bar{x} \pm s)$. Those fish which in the young stages can be found beyond the statistical limits of ls and ts generally equalize (compensate) their growth in the course of development, but there are always individuals which grow constantly over the variability range and do not compensate their growth. This may occur over or below the variability range. Those which grow over are of interest for us, for in such fish, provided they grow constantly over the variability range, it is likely that their constant better growth is inherent in their genotype. It is commonly known that every pond is different from the others as to its environmental conditions. If we observe a spawner or a select that grows constantly better in comparison with the population mean in different ponds, that is in different environmental conditions, then we can assume that the probability of having a significant genotype for growth for this spawner is high. If this is observed over a number of years, one may be nearly sure of this. Applying such a method one can overcome the need to compare offspring of a couple of spawners. This method also has an advantage in that it gives an individual estimate, and not an estimate for a couple. The theoretical basis for such a selection is the occurrence of the stabilizing effect of variability.

7.3.2 Example of selection for growth

An example of individual selection on the basis of the occurrent of the stabilizing effect of variability is givin in Fig. 4 and Fig. 5.

The population No. 3 (Fig. 4) was formed by the offspring of a cross between a male spawner from the Masurian Lake District and a female spawner of Polish origin. After reaching maturity a selection was made, from which 50 fish that remained were further observed. They were then tagged. Therefore the individual observations could have been done only on mature fish. I had no previous record of individual growth in this case. The majority of fish grew within the variability range given by ($\bar{x} \pm s$) or expressed in relative terms as (100 percent ± v percent). These fish had twice undergone selection for growth (from fry and after reaching maturity). In this population several especially good growing individuals were observed, for instance ♂349 or ♀315. The male grew constantly over the first limit, sometimes it grew out of the second variability limit. The male was especially valuable because it grew also constantly over the average growth of females, which is contrary to what we generally encounter in carp populations (see section 5). The female grew constantly over the second limit of variability given by ($\bar{x} + ts$) as may be seen from Fig. 4. Both these appear to be cases of genotypically conditioned exceptionally good growth, the constancy of growth shows it. The worst fish are those which show no constancy of growth; they can grow over the variability limits, then drop their growth into, or below, the variability range.

Fig. 5 was constructed in the same way as Fig. 4. The development of variability in this population gives a general picture of diminished variability and afterwards fluctuations around a stabilization level. The spawner No. 1400 grew constantly over the variability range, and we may expect that it will continue to grow in the same way, but spawner No. 1463, which grew over the range when young, dropped its growth curve into the variability range in the fifth year of life. We may classify it therefore as a "false jumper", the "true jumper" being No. 1400. A jumper is a carp which shows special swift growth in the young stages of life. If a fish diminishes its growth into the variability range, it means that it compensated its growth with the average of the population; this is a "false jumper", but if it continues the good growth, as is the case with No. 1400 and No. 735, it may be regarded as a "true jumper". It is sometimes difficult to decide whether the growth of a fish occurs over the limit or within the variability range, as is the case with No. 952 and No. 735. Both fish grew initially just on the border of variability. Spawner 952 dropped its growth curve into the variability range in the fourth year of life, that is, just after the passing of the stabilization effect; so it is only a "false jumper". But spawner No. 735 grew out of the range in the fifth year, so may be regarded as a "true jumper".

In the sixth year of life it is still too early to decide about these fish; one must still rear this family No. 1A for a longer period.

7.3.3 Categories of spawners according to type of growth in comparison with the range of variability

According to the type of growth of a spawner we may distinguish different categories of spawners.

(i) The best category, those spawners which grow constantly over the second variability limit, as for instance No. 315 from the "Ochaby" farms. These are very rare.

(ii) The spawners that grow between the first and second variability limits, as for instance the male No. 349 from the Ochaby farm.

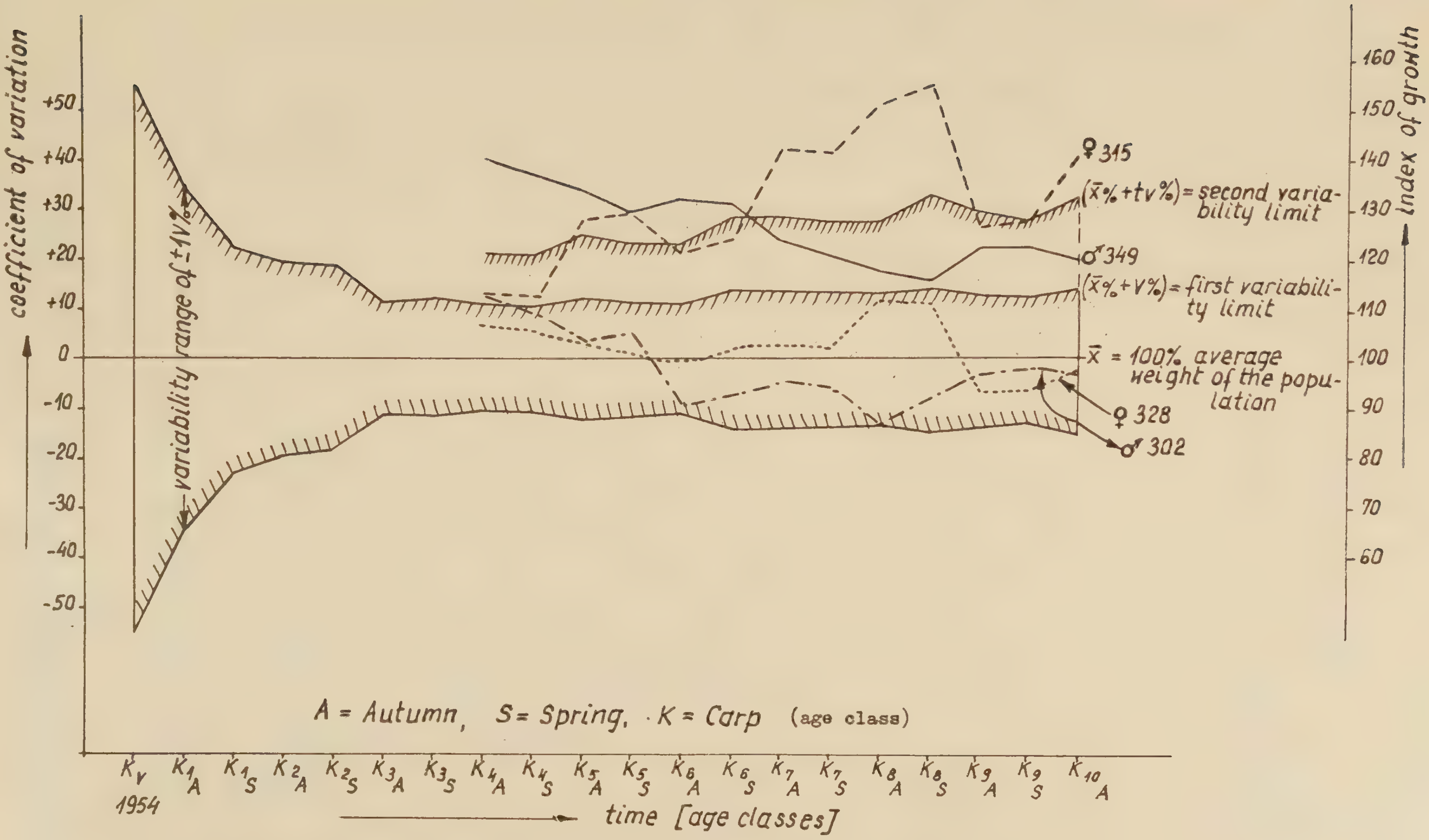

Fig. 4 An example of individual selection of spawners in sib-population No.3 (in experimental farm "Ochaby" 1954-1963)

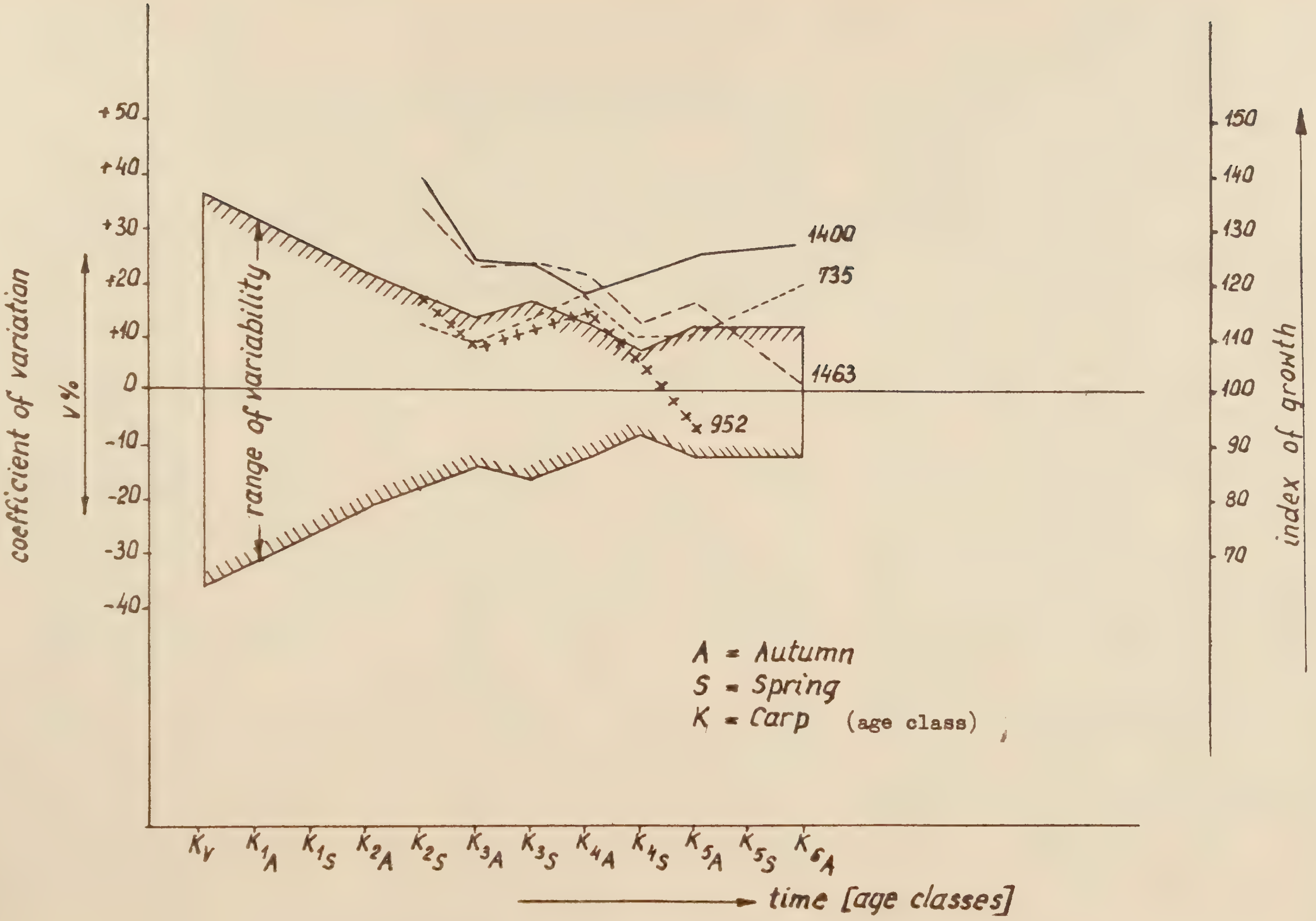

Fig. 5 An example of individual selection of spawners with early tagging. Sib-population No. 1A (experimental farm Gotysz)

(iii) All those fish that grow within the average ± first variability ($\overline{x} \pm s$) limits are the average fish.

(iv) Fish that grow below the first variability limit.

(v) Intermediate types. Spawners which grow slowly in the young stages but after stabilizing grow significantly better. Such fish, phenotypically poor, may be genotypically good and such a type of fish may be taken for further breeding. There can be also negative intermediate types, for instance a fish that grew very well in the first three years, then dropped its growth under the first variability limit ("false jumpers").

7.4 Tagging

The problem of tagging is very important in carp breeding and needs further study. I tagged, usually with silver tags with the number of population and a current number of the fish in the population; then, in order to ascertain that the fish would be recognized even if it lost the tag, I photographed the fish. The photographing helps in the selection, because we may consider the scaliness of the fish, which otherwise may be seen only twice a year. It is of interest to note that the carp males lost their tags more frequently than the females. The best tagging method was to clip the tags under the end of the dorsal fin. The losses of tags in populations thus tagged were negligible. As a result of such an approach one can make a catalogue of spawners living in the ponds.

8 BREEDING OF BLUE CARP

While inbreeding one sib-population of blue carp was observed in the F_2 generation (Wlodek, 1963). From two random samples of blue carp I have formed two blue sib-populations. The blue colour is most intense in July fry, that is in the youngest stage of life and diminishes in subsequent years. This diminishing of the intensity of colour shows differently on certain parts of the body's surface, the lateral line being a dividing line. The phenomenon of blue carp is termed the phenomenon of alampy by Schäperclaus (1961), and is due to the lack of guanine crystals in the skin. Both populations showed the diminution of intensity of blue colour in the skin, but in one of them it was more pronounced than in the other. Nevertheless the colour in K_3 was not the same as in normal carp, it was of a dark green type, whereas in the second population it was green and light blue. After inbreeding of the blue carp I observed in July fry a very intense blue colour, nearly black. The blue carps when crossed gave 100 percent blue offspring, therefore I think one can call this strain a blue variety: Cyprinus carpio var. cerulea. The original male spawner was of Polish origin from the experimental farms, the female was from a group of spawners imported in 1953 from the Masurian Lake District in northern Poland and its ancestry is not certain. In the upper Vistula region blue carp were not observed. The growth of blue fry was significantly different from that of other fry in the same pond. Later, in K_2, the blue carp also showed a better growth, but this difference in growth was in accordance with the stabilization effect. The difference in the second year of growth was less than in the first year. Therefore one can assume that the blue carp behave like "jumper" carp and their production may be important for systems of short production. The blue colour is a recessive trait which breeds according to the Mendelian laws. It is apparently linked with good growth in fry, but it is not linked with different types of body scaliness. The selection for growth of the existing population of blue carp is especially promising as they came from an unselected random sample. This population is now reared at the Golysz Experimental Farm.

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ESSAI DE DETERMINATION DES PERTES AU COURS DES DIFFERENTES PHASES DE L'ALEVINAGE DE LA CARPE

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Résumé

Pour faciliter le développement de la pisciculture de la Carpe commune (Cyprinus carpio) à Madagascar, nous avons essayé de mettre au point, en Station de pisciculture, une méthode pratique qui permette une production facile d'alevins sur une vaste échelle. La méthode qui a été retenue est la méthode indonésienne des kakabans. Cependant, malgré une production d'alevins intéressante, les résultats restent incertains et irréguliers selon les femelles utilisées. Pour en déterminer les causes, de nombreux comptages ont été effectués à tous les stades de la reproduction et de l'alevinage. Ces comptages montrent d'abord que la production d'oeufs par kilog de femelle est nettement inférieure à celle observée en Europe et ceci est en relation avec le phénomène de l'ovogénèse. Dans certains cas, la fécondation peut être mauvaise et l'incubation des oeufs contrariée par des phénomènes probablement imputables à l'état physique et à la composition chimique des eaux. La principale cause de disparition des alevins paraît provenir du facteur prédation et spécialement de la présence

de très nombreuses larves de Cybister. Pour lutter contre de facteur, nous avons été amenés à faire éclore les alevins dans des caisses grillagées: les résultats obtenus sont très intéressants mais la méthode n'est pas encore tout à fait au point.

DETERMINATION OF LOSSES DURING DIFFERENT STAGES OF RAISING CARP FRY

Abstract

In order to further the raising of carp, Cyprinus carpio, in ponds in Madagascar we have attempted to devise a practical method for large-scale raising of fry at our fish culture stations. The method found best was the Indonesian one of using 'kakabans'. Unfortunately, despite a good output of fry, there was some uncertainty and irregularity in breeding depending on the females used. In order to determine the reasons for this, observations were made at all stages of the reproductive process and during the raising of the fry. These observations showed first that egg production (in kg) per female is far below that observed in Europe and has something to do with the process of ovogenesis. In some instances fertilization may be poor and incubation of the eggs disturbed probably by physical condition and chemical composition of the waters. The main causes of disappearance of the fry seem to have been predators and the large number of larvae of Cybister. To overcome these difficulties we placed the eggs in screened cages in order to allow the fry to hatch. Despite the fact that this method has not yet been perfected, the results obtained are considered very good.

ENSAYO DE DETERMINACION DE LAS PERDIDAS EN EL CURSO DE LAS DISTINTAS FASES DEL ALEVINAJE DE LA CARPA

Extracto

Para facilitar el desarrollo de la piscicultura de la carpa común (Cyprinus carpio) en Madagascar, hemos ensayado de poner en marcha, en piscifactoría, un método práctico que permita una producción fácil de alevines en vasta escala. El método aplicado es el método indonesio de los "kakabans". Sin embargo, a pesar de una producción interesante de alevines, los resultados siguen siendo inciertos e irregulares según las hembras utilizadas. Para determinar las causas, se han efectuado numeroso recuentos en todas las fases de la reproducción y del alevinaje. Estos recuentos muestran en primer lugar que la producción de huevos por kilogramo de hembras es sensiblemente inferior a la observada en Europa, lo cual está en relación con el fenómeno de la ovogénesis. En ciertos casos, la fecundación puede ser defectuosa y perjudicarse la incubación de los huevos por fenómenos imputables probablemente al estado físico y a la composición química de las aguas. La principal causa de desaparición de los alevines parece provenir del factor predación y especialmente de la presencia de larvas muy abundantes de Cybister. Para luchar contra este factor, nos hemos visto obligados a realizar la eclosión de los alevines en cajas provistas de rejillas; los resultados obtenidos son muy interesantes, pero el método todavía no está completamente a punto.

1 INTRODUCTION

La carpe commune, race miroir (Cyprinus carpio), a été introduite à Madagascar en 1914 par le Dr Legendre.

Depuis cette date, la carpe s'est répandue sur une étendue égale au moins à la moitié de la superficie de l'Ile où elle semble avoir trouvé des conditions de vie favorables.

Les Malgaches, en général, et tout spécialement les populations des Hauts Plateaux, apprécient beaucoup ce poisson qui peut atteindre de grandes tailles et dont la chair assez grasse plaît beaucoup aux consommateurs.

A partir des années 1920, la pisciculture de la carpe en petits étangs et en milieu paysannal a commencé à se répandre; son élevage en rizière a également connu un certain succès, principalement dans deux régions localisées de la province de Tananarive : celle de Manjakandriana, à l'Est de la capitale, et celle de Betafo, à proximité de la ville d'Antsirabe. Toutefois, il semble bien que les diverses méthodes d'élevage n'ont pas connu le succès qu'on aurait pu en attendre, faute pour les pisciculteurs et les rizi-pisciculteurs, de pouvoir se procurer ou produire des alevins en quantités suffisantes.

Les jeunes carpillons utilisés proviennent, en général, de la reproduction naturelle non contrôlée qui a lieu dans les lacs, rivières, marais, etc. Certains pêcheurs capturent ces carpillons et les revendent aux éleveurs à un prix souvent fort élevé qui freine les possibilités d'approvisionnement.

Cette pénurie d'alevins, dans un milieu économique où le pouvoir d'achat est très faible, constitue, à notre avis, la raison primordiale pour laquelle l'élevage de la carpe n'a pas connu une plus grande extension.

C'est pourquoi la section de recherches piscicoles du Service des Eaux et Forêts, puis la division de recherches piscicoles du Centre Technique Forestier Tropical qui lui a succédé, se sont particulièrement intéressées à l'étude de la reproduction de la carpe dans les stations de pisciculture et ont essayé de mettre au point une méthode pratique qui permette une production facile d'alevins sur une vaste échelle.

Ces expériences ont été effectuées dans les trois stations de la Sisaony, d'Analamazaotra-Périnet et d'Ampamaherana. On trouvera en annexe leurs principales caractéristiques écologiques.

Diverses méthodes de reproduction ont été utilisées : méthode naturelle, méthode naturelle améliorée sur étang à fond couvert d'herbes, méthode Dubisch,méthode israélienne, mais c'est finalement la méthode indonésienne des Kakabans qui a été retenue.

Cependant, cette méthode, tout en donnant une production d'alevins intéressante, n'est pas encore parfaite.

La reproduction de la carpe reste un phénomène capricieux. Certaines femelles donnent de bons résultats, d'autres des résultats médiocres ou même nuls, si bien que le nombre d'alevins obtenus par pose est essentiellement variable.

Depuis 1960, nous utilisons comme géniteurs des sujets appartenant à une race hautement sélectionnée ayant pour origine une pisciculture française de Sologne et connue sous le nom de carpe royale.

La plupart des recherches entreprises sur la carpe à Madagascar depuis quelques années sont faites à partir de cette race qui est venue remplacer la carpe miroir traditionnelle, peu à peu retournée à la forme ancestrale à écailles et à corps allongé.

Au cours de plusieurs campagnes de reproduction, nous avons essayé d'analyser quelles pouvaient être les différentes causes qui étaient à l'origine des résultats incertains ou médiocres que nous obtenions en matière de production d'alevins. Nous avons donc été amenés à examiner de très près toutes les phases de la reproduction, depuis la ponte jusqu'au stade où les alevins sont bons à être distribués.

Nous allons donc passer en revue toutes ces phases, mais il convient d'abord de noter que, sur les stations considérées, les deux sexes sont toujours séparés et stockés dans des étangs différents. Mâles et femelles ne sont réunis, en général à raison d'une femelle pour deux mâles, qu'au moment de la reproduction.

A Madagascar, les carpes sont aptes à se reproduire à partir de l'âge de 2 ans.

La nourriture distribuée consiste en un mélange de son de riz cuit, de sang séché, de tourteaux d'arachide et de poudre d'os. Parfois, nous distribuons aussi des vers de terre vivants.

La période de reproduction débute en général vers fin septembre, début octobre et semble s'achever vers fin décembre, début janvier.

2 LA PONTE ET LA FECONDATION

A plusieurs reprises, depuis 1961, nous avons effectué des comptages d'oeufs, d'abord sur des carpes miroir provenant de la souche de 1914, ensuite sur des carpes royales introduites à Madagascar en 1959.

Ces comptages ont été faits soit après autopsie, soit après ponte sur balais (méthode des Kakabans). Les résultats obtenus sont indiqués ci-dessous.

2.1 Nombre d'oeufs

2.11 Comptage après autopsie

A la Sisaony, en 1961, 2 carpes miroir pesant respectivement 1,500 kg et 1,730 kg (âge probable 3 ans), présentent les caractères suivants :

1,500 kg : poids total des ovaires .... 279 g
nombre total d'oeufs 257.250

1,730 kg : poids total des ovaires .... 301 g
nombre total d'oeufs 283.000

Remarque : Les oeufs sont de très petite taille et ces carpes, bien que considérées comme reproductrices, n'ont pas présenté, fin 1961, de signes de maturité bien nets, mais on atteint ici et même on dépasse le chiffre toujours mis en avant par les auteurs classiques traitant de la carpiculture, de 100.000 oeufs par kg de poids vif.

2.12 Comptage d'oeufs pondus sur Kakabans

Ces comptages ont été effectués à la station d'Ampamaherana. Le nombre d'oeufs pondus a été relevé sur quelques surfaces de 1 dm2, choisies dans des zones de ponte dense et de ponte clairsemée pour avoir une moyenne.

2.121 Carpes miroir

Comptage d'oeufs d'une femelle pesant 1 kg (âge probable 2 ans) :

Date de la ponte : 7.12.1961 qui est aussi le jour de comptage des oeufs.

Opérations effectuées

Premier cadre de 6 éléments			Deuxième cadre de 6 éléments		
Placeau de 1 dm2	Nombre d'oeufs fécondés	Nombre d'oeufs non fécondés	Placeau de 1 dm2	Nombre d'oeufs fécondés	Nombre d'oeufs non fécondés
1	85	8	1	120	15
2	70	6	2	100	12
3	90	5	3	90	8
4	100	12	4	85	5
5	75	4	5	65	4
6	40	3	6	42	3
7	38	5	7	34	4
8	50	6	8	28	2
9	52	2	9	40	2
10	35	3	10	25	2
	635	54		629	57

Moyenne par dm2 fécondés : $\frac{635 + 629}{20} = 63,2$

Moyenne par dm2 non fécondés : $\frac{54 + 59}{20} = 5,55$

Surface des deux cadres (2 x 1,50 m) x 2 = 600 dm2
Nombre d'oeufs fécondés pondus pour les deux cadres : 63,2 x 600 = 37.920 oeufs
Nombre d'oeufs non fécondés pondus pour les deux cadres : 5,55 x 600 = 3.330 oeufs
(8 pour cent du total)

Total d'oeufs pondus : 37.920 + 3.330 = 41.250

Les années précédentes, on avait trouvé :

- pour une femelle de 500 g : 14.625 oeufs fécondés
1.395 oeufs non fécondés (8 à 9 pour cent du total)
Total 16.020
- pour une femelle de 1 kg : 25.515 oeufs fécondés
1.755 oeufs non fécondés (6 à 7 pour cent du total)
Total 27.270
- pour une femelle de 1,500 kg : 37.710 oeufs fécondés
2.745 oeufs non fécondés (6 à 7 pour cent du total)
40.455

Nous constatons donc que ces chiffres d'oeufs pondus sont très faibles par rapport à ceux observés en Europe, où, d'ailleurs, il convient de le signaler, on utilise comme carpes femelles génitrices des sujets en général beaucoup plus gros (des carpes femelles de 5, 6, 7, 8 kg ne sont pas rares) et nous sommes loin cette fois des 100.000 oeufs par kg de poids vif annoncés par tous les auteurs traitant de carpiculture.

Comptage d'oeufs de 4 femelles de carpe royale âgées de 3 ans

Poids de la femelle .... 2 kg Mise en charge du .... 1/10/63 Ponte du .... 2/10/63 Surface totale de 2 cadres kakabans : (24 x 15) X 2 = 720 dm2 Total des oeufs fécondés comptés sur 10 placeaux de 1 dm2 .... 1.341 Total d'oeufs non fécondés .... 74 Nombre total d'oeufs fécondés : $\frac{1.341 \times 720}{10} = 96.552$ Nombre total d'oeufs non fécondés : $\frac{74 \times 720}{10} = 5.328 = 5,2\ \%$ Total d'oeufs pondus : 101.880	Poids de la femelle .... 2,100 kg Mise en charge du .... 1/10/63 Ponte du .... 2/10/63 Surface totale de 2 cadres kakabans : (24 x 15) x 2 = 720 dm2 Total des oeufs fécondés comptés sur 10 placeaux de 1 dm2 .... 1.346 Total d'oeufs non fécondés .... 78 Nombre total d'oeufs fécondés : $\frac{1.346 \times 720}{10} = 96.912$ Nombre total d'oeufs non fécondés : $\frac{78 \times 720}{10} = 5.616 = 5,4\ \%$ Total d'oeufs pondus : 102.528
Poids de la femelle .... 2 kg Mise en charge du .... 8/10/63 Ponte du .... 9/10/63 Nombre total d'oeufs fécondés : $\frac{1.240 \times 720}{10} = 89.280$ Nombre total d'oeufs non fécondés : $\frac{70 \times 720}{10} = 5.040 = 5,3\ \%$ Total d'oeufs pondus : 94.320	Poids de la femelle .... 1,700 kg Mise en charge du .... 8/10/63 Ponte du .... 9/10/63 Nombre total d'oeufs fécondés : $\frac{1.095 \times 720}{10} = 78.840$ Nombre total d'oeufs non fécondés : $\frac{73 \times 720}{10} = 5,256 = 6,2\ \%$ Total d'oeufs pondus : 84.096

2.122 Carpes royales

Comptage d'oeufs d'une femelle de 1,400 kg (âge : 2 ans. Octobre 1962)

Les oeufs sont comptés sur 7 placeaux de 1 dm2 chacun, pris sur 2 cadres de 300 dm2 chacun, en choisissant les endroits où la ponte paraissait être dense et ceux où elle était clairsemée de façon à obtenir une moyenne valable.

1er cadre : 300 dm2

	Zone de ponte maximum		Zone de ponte minimum	
Oeufs fécondés	80	126	40	10
Oeufs non fécondés	10	14	4	2
	90	140	44	12

2ème cadre : 300 dm2

	Zone de ponte maximum		Zone de ponte minimum
Oeufs fécondés	120	80	10
Oeufs non fécondés	20	11	3
	140	91	13

La moyenne des oeufs fécondés par dm2 peut donc être évaluée à : $\frac{466}{7}$ = 67 oeufs et la moyenne des oeufs non fécondés par dm2 à : $\frac{64}{7}$ = 9 oeufs.

La ponte totale pour 2 cadres, soit en tout 600 dm2, pourrait donc être évaluée à : 40.200 oeufs fécondés,
5.400 oeufs non fécondés, soit 11,8 pour cent du total pondu.

Remarquons en passant que ces chiffres sont toujours du même ordre de grandeur que ceux obtenus en 1961-1962 : soit environ 40 000 oeufs pondus pour une femelle de 1,500kg.

Nous constatons que ces chiffres sont assez élevés et que le nombre des oeufs fécondés est lui aussi très important puisque nous avons respectivement 96.552, 89.280, 96.912 et 78.840 oeufs fécondés. Le nombre d'oeufs blancs variant entre 5.000 et 5.600.

On peut joindre à ces résultats celui de 1962 cité plus haut : 45.600 oeufs (dont 5.400 non fécondés) pour une femelle de carpe royale âgée de 2 ans et pesant 1,400kg.

2.123 Comparaison des carpes royales et des carpes miroir

Ces chiffres peuvent être comparés avec ceux des années précédentes dans la même station. Les reproducteurs employés étaient alors des carpes miroir.

Pendant la campagne 1961-1962, avec une femelle "miroir" de 1 kg, nous avons eu 41.250 oeufs dont 3.330 oeufs blancs.

Les années précédentes, on avait trouvé :
- pour une femelle de 500 g : 16.020 oeufs dont 1.395 oeufs non fécondés;
- pour une femelle de 1 kg : 27.270 oeufs dont 1.755 oeufs non fécondés;
- pour une femelle de 1,500 kg : 40.455 oeufs dont 2.755 oeufs non fécondés.

a) Il semble donc qu'à poids égal, une carpe royale ponde plus qu'une carpe miroir puisque, pour une carpe miroir de 1,500 kg, nous avons obtenu 40.455 oeufs alors qu'avec une carpe royale de 1,700 kg, nous avons obtenu 84.096 oeufs.

b) Si, tenant compte du fait que le nombre d'oeufs pondus est à peu près proportionnel au poids et prenant pour base :
- une femelle de 0,500 kg pondant 16.020 oeufs,
- une femelle de 1 kg pondant 27.270 oeufs,
- une femelle de 1,5 kg pondant 40.455 oeufs,

en ramenant au poids de 2 kg, nous avons respectivement pour une femelle miroir de 2 kg:
- 16.020 x 4 = 64.080 oeufs
- 27.270 x 2 = 54.540 oeufs
- 40.455 x $\frac{4}{3}$ = 53.940 oeufs.

Ce nombre d'oeufs pondus par une femelle miroir de 2 kg est faible par rapport à celui de femelles de carpe royale qui, pesant respectivement 2 kg et 2,100 kg, pondent 101.880 et 102.528 oeufs. On peut donc dire qu'à poids sensiblement égal, une carpe royale pond environ 1,8 fois plus qu'une carpe miroir.

Il semble enfin que, pour les deux races, la proportion d'oeufs blancs varie généralement entre 5 et 9 pour cent.

2.2 Discussion sur la ponte

De tous les comptages faits, il résulte malgré tout que, même dans le cas de carpe royale qui semble pondre davantage, nous sommes toujours très loin des 100.000 oeufs par kg de poids vif et pourtant les quelques résultats obtenus lors d'autopsie confirment largement ce dernier chiffre.

Il y aurait donc, chez les carpes d'élevage, une ovogénèse difficile qui, pour des raisons qui nous échappent encore, conduirait à une production assez faible d'oeufs mûrs aptes à être expulsés et fécondés.

Ceci serait peut-être en relation avec des questions de nourriture car nous avons toujours remarqué, dans nos étangs, un déficit très net de zooplancton par rapport à ce qui existe par exemple en Europe.

Nous avons également remarqué que les bonnes reproductions correspondent parfois assez curieusement à un rythme bisannuel avec une bonne année sur deux.

Par exemple, à la station de la Sisaony :

1959 : reproduction nulle,
1960 : production moyenne d'alevins,
1961 : reproduction à peu près nulle,
1962 : production assez bonne.

Ceci pourrait résulter également d'une difficulté dans l'élaboration des oeufs mûrs.

A propos de la ponte, nous avons également observé que certaines femelles présentant pourtant un abdomen assez gonflé, mises en présence de mâles, ne pondent pas. Le pourcentage des femelles qui ne pondent pas atteint parfois 40 à 50 pour cent. Ceci signifie peut-être que l'ovogénèse n'est pas parvenue à son aboutissement normal.

Parfois il arrive aussi que des femelles mises en présence de mâles pondent une première fois, puis une deuxième fois quelque temps après, après avoir été séparées des mâles.

Il peut se faire également que des femelles pondent en l'absence de mâles. Il semblerait, dans ce cas, que la simple présence de l'herbe suffise pour déclencher le réflexe de ponte.

Notons également que la présence de boue très fine ou de pellicules d'hydroxyde ferrique venant se déposer soit sur les herbes, soit sur les fibres des balais, provoque chez la femelle une certaine répulsion qui peut sans doute expliquer certaines pontes irrégulières ou même nulles.

En résumé, nous ne sommes pas encore parvenus à faire pondre à coup sûr toutes les carpes reproductrices et nous pensons que la plupart des difficultés rencontrées proviennent d'une ovogénèse qui ne se fait pas normalement dans tous les cas, sans que nous puissions cependant savoir avec certitude la cause d'un tel phénomène que nous attribuons provisoirement à des questions de qualité de la nourriture.

Il serait donc intéressant qu'un spécialiste puisse étudier l'évolution du développement des oeufs en autopsiant à intervalles réguliers un certain nombre de carpes femelles pour voir comment se fait chez les carpes d'élevage l'ovogénèse jusqu'au moment de l'expulsion des oeufs.

D'ores et déjà, nous avons pris des dispositions pour marquer un certain nombre des carpes reproductrices que nous possédons sur nos stations afin de pouvoir déterminer si certains individus présentent des dispositions plus ou moins marquées pour une bonne reproduction ou non.

2.3 Discussion sur la fécondation

En ce qui concerne la fécondation, l'examen des tableaux ci-dessus montre que le pourcentage des oeufs blancs non fécondés varie entre 5 et 12 pour cent, mais on a aussi observé que certaines pontes pour lesquelles les comptages n'ont pas été faits présentaient une très grande proportion d'oeufs blancs indiquant par là que la fécondation s'était faite dans de très mauvaises conditions.

Une mauvaise fécondation peut avoir deux causes :

- ou bien les spermatozoïdes ont pu être émis en quantité insuffisante, ce qui a fort bien pu se produire quand de jeunes mâles de 2 ans étaient utilisés pour la deuxième fois au cours d'une saison et ce qui malheureusement a parfois été rendu nécessaire quand nous disposions d'un nombre insuffisant de mâles;

- ou bien les spermatozoïdes émis en quantité suffisante ont été stérilisés par des phénomènes d'oxydo-réduction.

En effet, on sait maintenant qu'en utilisant une poudre à base d'acide ascorbique et de sulfate cuivreux, on arrive à stériliser les organismes inférieurs vivants dans l'eau en l'espace de quelques secondes sans pour cela les tuer. Mais ils ne possèdent plus la faculté ni de se reproduire, ni même de se diviser. Ainsi, avec de l'eau prise dans un étang de l'Institut Pasteur à Tananarive, il suffit de 36 mg de cette poudre pour obtenir un résultat positif.

Il n'est donc pas impossible qu'au contact des acides nucléiques du spermatozoïde, l'action des substances oxydantes telles que l'hydroxyde ferrique, très abondant dans les eaux des hauts plateaux, intervienne dans un sens d'oxydo-réduction par échange d'électrons et provoque une stérilisation instantanée des spermatozoïdes sans les tuer.

Par ailleurs, nous savons aussi (Schäperclaus, 1962), que la mobilité des spermatozoïdes est très ralentie dans des eaux à pH voisin de 6.

De toutes manières, les carpiculteurs des régions à sol acide du Nord de l'Allemagne (Hambourg) attachent une grande importance à la nécessité d'avoir une eau présentant une teneur suffisante en carbonates.

Pour se rendre compte de la mobilité des spermatozoïdes dans différents milieux, nous avons entrepris, en 1963, avec l'aide du Dr Dodin de l'Institut Pasteur de Tananarive, une série d'expériences qui montrent le comportement du sperme placé dans différentes solutions salines.

L'intérêt de ces expériences réside dans le fait qu'à plusieurs reprises, nous avons pu penser que le faible pourcentage d'alevins obtenus pouvait peut-être provenir d'une mauvaise fécondation des oeufs par suite d'une défaillance d'un grand nombre de spermatozoïdes aussitôt après leur émission dans l'eau.

Les constatations faites ont été très intéressantes et rejoignent en partie celles faites par Woynarovich (1962) sur l'action du ClNa. C'est ainsi qu'en milieu naturel: sperme non dilué, les spermatozoïdes semblent vivre de 10 à 20 minutes à la température du laboratoire, mais en ayant des mouvements très faibles.

Dilué à raison du 1/10ème (0 cm^3 de sperme, 0 cm^{3}9 d'eau), soit avec de l'eau du robinet, pH = 6,4, soit avec de l'eau d'un étang de l'Institut Pasteur, pH = 6,4, on observe une gélification brutale de toute la masse après une phase très courte d'accélération générale des mouvements de tous les spermatozoïdes et ceci que ce soit à la température du laboratoire ou à 28° dans l'étuve.

En milieu tamponné P.B.S. à pH = 7 (4 sels : ClK, ClNa, PO_4HNa_2, PO_4H_2K), les spermatozoïdes sont encore partiellement vivants après une nuit passée à l'étuve, à la température de 28°. Il n'y a pas gélification.

En présence de radicaux libres : acide ascorbique + SO_4Cu, il y a gélification rapide.

Nous avons ensuite essayé de voir quelle pouvait être l'action de chaque sel et, pour cela, nous avons utilisé 7 tubes, dans chacun desquels nous avons mis du sperme dilué au 1/10ème.

Tube n°I : 0cm^{3}9 eau bidistillée + ClNa à 8‰, sérum physiologique;

Tube n°II : 0cm^{3}9 eau bidistillée + PO_4HNa_2 à la concentration physiologique;

Tube n°III : 0cm^{3}9 eau bidistillée + PO_4H_2K à la concentration physiologique;

Tube n°IV : 0cm^{3}9 eau bidistillée + ClK à la concentration physiologique;

Tube n°V : 0cm^{3}8 eau bidistillée + 0 cm^{3}1 d'une solution tamponnée pH = 7 (PO_4HNa_2 + PO_4H_2K)

Tube n°VI : 0cm^{3}7 eau bidistillée + 0cm^{3}2 d'une solution pH = 7 à ClNa, PO_4HNa_2 et PO_4H_2K;

Tube n°VII : 0cm^{3}6 eau bidistillée + 0cm^{3}3 d'une solution pH = 7. Milieu P.B.S. avec les 4 sels.

Au bout de 10 minutes, à la température du laboratoire, nous avons observé :

I : Gélification nulle
II : " légère ++
III : " moyenne +++
IV : " complète ++++
V : " moyenne +++
VI : " nulle
VII : " nulle

Donc ClNa semble avoir un pouvoir anticoagulateur dû à l'ion Na (car ClK n'a pas de pouvoir).

Il semble donc que l'eau des étangs de nos stations ne convienne pas toujours très bien pour la mobilité du sperme des carpes.

Ces expériences seraient à compléter, compte tenu de l'analyse chimique des eaux des étangs : en particulier présence de silicates complexes de Fer et d'Alumine. Il faudrait également essayer avec des sels de Manganèse, avec des suspensions de latérite. Mais, d'ores et déjà, il semble bien qu'on puisse affirmer qu'il y a dans les eaux des étangs de nos stations des facteurs chimiques qui ne favorisent pas la mobilité du sperme des carpes, bien que, dans les conditions de l'expérience, la gélification n'ait jamais été absolument instantanée.

3 L'INCUBATION

Dans les trois stations, l'incubation dure en général de 3 à 5 jours.

Au cours de cette courte période, des pertes importantes surviennent, qu'il est difficile de chiffrer.

Théoriquement, on pourrait les évaluer en comptant les oeufs fécondés au départ et le nombre d'alevins au jour de l'éclosion, mais ce dernier comptage est difficile à réaliser compte tenu de l'extrême petite taille des alevins à la naissance et de la difficulté qu'il y a à les voir et à les manipuler lors de l'éclosion.

Les pertes en cours d'incubation sont dues à deux causes :

Il y a d'abord le facteur prédation car nous avons souvent remarqué que, lorsque les kakabans chargés d'oeufs sont placés dans les étangs d'éclosion, ils attirent en particulier des quantités de Cybister adultes qui doivent consommer une grande quantité d'oeufs et ceci malgré la destruction quotidienne des adultes et de leurs larves. D'autres prédateurs peuvent aussi jouer un rôle destructif : Gambusies, Hémiptères aquatiques, larves d'Odonates, de Gyrins, etc.

Il y a ensuite le fait que, dans les conditions particulières de nos stations à Madagascar, les eaux sont toujours chargées de fines particules de boue qui se déposent très rapidement sur tous les supports immergés et en particulier sur les oeufs, les empêchant ainsi de respirer normalement.

L'hydroxyde ferrique, toujours présent dans les eaux légèrement acides ayant ruisselé sur la latérite, joue aussi le même rôle physique avec, peut-être en plus, un rôle osmotique toxique.

4 LE GROSSISSEMENT DES ALEVINS

Le but poursuivi dans les trois stations considérées est d'obtenir le plus rapidement possible des alevins de carpes bons à être distribués aux éleveurs ou aux rizipisciculteurs, c'est-à-dire, en fait, des alevins ayant de 4 à 5 cm de long.

Le grossissement est, en général, réalisé dans des étangs de plusieurs ares chacun, dans la mesure où l'on a suffisamment de place.

L'idéal serait qu'on ne charge pas les étangs de grossissement à plus de 50.000 alevins par hectare, compte tenu du fait que les eaux des hauts plateaux malgaches sont très pauvres en nourriture naturelle et spécialement en zooplancton, bien que celui-ci soit assez bien représenté qualitativement par des Cladocères, des Ostracodes, des Copépodes, de nombreuses espèces de Rotifères, des larves de Chironomes, etc...

Quand la charge est de l'ordre de grandeur que nous venons d'indiquer, la taille minimum de 4 à 5 cm est en général atteinte au bout de 25 à 30 jours, d'autant plus qu'on ne ménage pas la distribution de nourriture artificielle : son de riz, tourteaux, sang séché, etc.

Mais, quand la charge est plus forte, on constate d'abord un ralentissement très net de la croissance des sujets qui restent très maigres, avec une tête de dimension disproportionnée par rapport au corps et surtout des inégalités considérables dans les croissances individuelles. Tout se passe comme si certains sujets grandissent normalement à côté de nombreux autres qui restent très petits.

5 LA MORTALITE DES ALEVINS

5.1 Facteurs de prédation et de concurrence

Au cours de la période de grossissement, le jeune alevin est soumis à une prédation intense et, après la naissance, il semble bien que ce sont ces facteurs de prédation qui jouent un rôle essentiel et qui sont la principale cause de la mortalité des alevins. Il y a, bien entendu, des mortalités naturelles dues à de mauvaises conformations de quelques jeunes poissons, mais elles doivent être relativement peu importantes.

Parmi les prédateurs, très fréquents dans les eaux malgaches, on peut indiquer les larves d'insectes, particulièrement celles de Cybister.

Dans la pratique, le meilleur moyen de lutter contre elles est de passer chaque jour, le long des bords de l'étang, une épuisette en tulle moustiquaire qui permet de les capturer facilement car les larves se trouvent en général à l'affût sur les herbes du bord. Tuées, elles sont immédiatement rejetées dans l'étang où elles contribuent à la nourriture des alevins.

Les larves d'Odonates anisoptères sont également toujours très abondantes et ce sont des larves très prédatrices.

Les larves de Gyrins semblent moins fréquentes.

Parmi les insectes adultes, signalons surtout les Dytiscides, les hémiptères aquatiques : Belostoma, Ranatra, Nepa, etc.

On peut également avoir affaire à de petits poissons carnassiers :

- Les Gambusies, dont il est toujours difficile de se débarrasser car elles se réfugient dans de minuscules flaques d'eau et elles arrivent toujours par les canaux, même quand ils sont munis de grillage;
- Les Tilapia qui, venant des étangs voisins peuvent avec facilité, parvenir dans l'étang d'éclosion par les canaux et il est hors de doute que les Tilapia, même jeunes, n'hésitent pas à se nourrir de proies vivantes.

Les Tilapia en grossissant peuvent donner lieu à une prédation très forte avec seulement quelques gros poissons.

Il arrive aussi avec certaines méthodes : méthode israélienne, méthode naturelle améliorée, que les géniteurs carpes soient maintenus un certain temps au milieu de très petits alevins. Il est certain que cela doit aboutir à du cannibalisme. Avec la méthode des kakabans, ce risque ne se présente pas puisque les oeufs sont tout de suite, dès la ponte, transvasés dans l'étang d'éclosion, mais avec la méthode Dubisch, cela peut arriver, quand par exemple, il est difficile de vider puis de remplir rapidement la frayère par suite d'eau trop sale ou en quantité insuffisante. Nous savons, en effet, que dans la méthode Dubisch classique, on fait baisser le niveau d'eau pendant au maximum 1/4 d'heure afin de ne pas tuer les oeufs, juste le temps de récupérer les géniteurs qui sont venus se réfugier dans les fossés périphériques.

Parmi les autres prédateurs possibles, signalons les couleuvres, particulièrement le genre Liopholidophis, fréquentes au voisinage des étangs.

Enfin, les oiseaux sont toujours très nombreux sur les étangs de nos stations à cause des réserves que constituent les grands marais qui représentent de vastes étendues dans la campagne malgache. Ces oiseaux chassent souvent de nuit : spécialement les bihoreaux (Nycticorax) et il est très difficile de lutter contre eux, que ce soit au fusil, au piège ou au poison. Les oiseaux les plus néfastes semblent être le martin-pêcheur (Corithornis cristata), le crabier blanc, le bihoreau, certains hérons. Les cormorans, beaucoup plus sauvages n'apparaissent que très rarement dans les stations.

A côté du facteur prédation, intervient aussi, dans une certaine mesure, le facteur concurrence du point de vue nourriture. Les concurrents principaux sont les têtards de grenouille de l'espèce Ptychadaena madagascariensis. Ces têtards apparaissent en très grande quantité vers le mois de septembre, justement à l'époque où commence la reproduction de la carpe et ils sont de grands consommateurs de nourriture artificielle et probablement aussi naturelle.

Il convient donc de les récolter et de les tuer exactement comme on le fait avec les larves de Cybister pour ensuite rejeter les cadavres dans l'eau où, en se décomposant et en produisant du plancton, ils servent à leur tour de nourriture pour les alevins.

5.2 Essais de détermination des pertes imputables aux prédateurs ou concurrents

5.21 Description et résultats

Afin de suivre, par des comptages, les alevins dans les premières semaines de leur vie et de mesurer ainsi quelle pouvait être l'action des prédateurs ou des concurrents, nous avons isolé, à plusieurs reprises, des lots de 100 oeufs environ, obtenus en découpant des parties de balais et ces lots ont été placés soit dans des seaux immergés couverts de treillis moustiquaire, soit dans des aquariums, soit directement dans de petits étangs, soit enfin, à partir de 1963, dans de petites caisses cubiques (0,40 m x 0,40 m x 0,40 m) constituées d'un cadre en bois très léger garni également de toile très fine.

A partir de 1964, afin d'essayer de nous mettre dans des conditions plus proches de celles de l'éclosion normale, nous avons placé dans de grandes caisses de 0,900 m^3 un élément entier de kakabans par caisse.

Dans ce dernier cas, les jeunes alevins étaient nourris chaque jour par distribution d'un jaune d'oeuf cuit et soigneusement émietté.

Les résultats de nos essais sont indiqués ci-dessous.

Essai n° 1, en 1961, à la Sisaony :

- 100 oeufs sont placés dans un aquarium contenant 60 l d'eau distillée,
- 100 oeufs sont placés dans un aquarium contenant 60 l d'eau prise dans l'étang de ponte,
- 100 oeufs sont placés dans le petit étang n°6 d'éclosion pour observer dans quelles conditions se font l'incubation et l'éclosion.

Les lots placés dans les deux aquariums devaient, pensions-nous, nous montrer quelle pouvait être l'influence des boues et des prédateurs sur l'incubation des oeufs et la vie des alevins. Malheureusement, les expériences faites en aquarium se sont soldées par un échec complet.

Dans l'étang d'éclosion n° 6 où les oeufs avaient été placés le 23 décembre 1961, on a récupéré 48 alevins le 18 janvier 1962. La proportion d'alevins vivants de 3 à 4 semaines a donc atteint, au cours de cet essai, presque 50 pour cent de la ponte, ce qui constitue un beau résultat.

IV/E-3

Essai n° 2, en 1961, à Ampamaherana :

- 8 lots de 100 oeufs environ chacun ont été placés dans 8 petits étangs d'éclosion de la série F de 4 m^2 chacun, les oeufs restant bien fixés sur les parties des kakabans sur lesquelles ils avaient été pondus.

Sur ces 8 lots, les oeufs blancs ont été comptés au début de l'expérience et, ensuite, on a compté les alevins récupérés le jour de l'éclosion puis les 7ème, 14ème et 21ème jour après l'éclosion.

Les résultats obtenus sont donnés dans le tableau suivant :

Mise en place des lots le mercredi 6/12/1961

Comptage des alevins le jour de l'éclosion	Comptage des alevins le 7è j après l'éclosion.	Comptage des alevins le 14è j après l'éclosion	Comptage des alevins le 21è j après l'éclosion
F-23 Nbre d'oeufs fécondés .... 88 Nbre non fécondés 20 Total ...... 108 Lundi 11/12/61 Constatation d'alevins. Vidange de contrôle soit 6 alevins (6,8% des oeufs fécondés)	F-21 Nbre d'oeufs fécondés .... 82 Nbre non fécondés 22 Total ...... 104 Lundi 18/12/61 Vidange de contrôle soit 39 alevins récupérés (47,6% des oeufs fécondés)	F-19 Nbre d'oeufs fécondés .... 80 Nbre non fécondés 30 Total ...... 110 Mardi 26/12/61 Vidange de contrôle soit 30 alevins récupérés (37,5% des oeufs fécondés)	F-17 Nbre d'oeufs fécondés ....96 Nbre non fécondés 12 Total ..... 108 Mardi 2/1/62 Vidange de contrôle soit 20 alevins récupérés (20,8% des oeufs fécondés)
F-22 Nbre d'oeufs fécondés .... 90 Nbre non fécondés 16 Total ...... 106 Lundi 11/12/61 Constatation d'alevins. Vidange de contrôle soit 10 alevins (11,1% des oeufs fécondés)	F-20 Nbre d'oeufs fécondés .... 86 Nbre non fécondés 20 Total ...... 106 Lundi 18/12/61 Vidange de contrôle soit 36 alevins récupérés (41,8% des oeufs fécondés)	F-18 Nbre d'oeufs fécondés .... 80 Nbre non fécondés 29 Total ..... 109 Mardi 26/12/61 Vidange de contrôle soit 34 alevins récupérés (42,5% des oeufs fécondés)	F-16 Nbre d'oeufs fécondés .... 94 Nbre non fécondés 16 Total .... 110 Mardi 2/1/62 Vidange de contrôle soit 26 alevins récupérés (27,66% des oeufs fécondés)
Observations Les alevins étant très petits au moment de la vidange, perte certaine d'une grande partie d'entre eux.			Observations Présence de larves de Cybister à la vidange.

Si l'on ne tient pas compte des résultats du jour de l'éclosion et du 7ème jour (alevins encore trop fragiles et difficiles à capturer), on trouve que les alevins vivants 14 jours après l'éclosion représentent plus du 1/3 des oeufs pondus et que, du 14ème au 21ème jour, l'effectif diminue pour ne plus représenter, le 21ème jour, qu'environ 1/4 des oeufs pondus.

Il semble donc qu'il y a de grosses pertes dans le jeune âge. Ces pertes peuvent sans doute s'expliquer, en partie, par les prédateurs et par un certain manque d'espace vital : les bassins F en question faisant environ 4 m^2. D'autre part, les eaux chargées de matières en suspension très fines provoquent sûrement la mort d'un grand nombre d'oeufs. Enfin, l'acidité de l'eau n'est sans doute pas excellente. Il y a peut-être aussi en cause une certaine fragilité des alevins dans les premiers âges.

Au cours du même essai, un lot de 100 oeufs environ a été placé dans un seau recouvert d'une toile moustiquaire en nylon qui a été immergé dans l'étang B-37. Le but de cette expérience était de permettre de savoir si le fait d'empêcher les prédateurs de venir au contact des oeufs en cours d'incubation avait une influence heureuse sur les éclosions.

Au début, il y avait exactement 106 oeufs dont 16 oeufs blancs (15 pour cent du total). Cette expérience s'est soldée par un échec complet puisqu'il n'y a eu aucune éclosion. Le 4ème jour, tous les oeufs étaient blancs.

Une deuxième expérience a été tentée, toujours dans le même esprit. Pour cela, on a placé 107 oeufs, dont 25 oeufs blancs (23 pour cent du total), dans un seau contenant de l'eau distillée pour voir si l'influence des boues qui peuvent se déposer sur les oeufs en cours d'incubation était importante.

Cette expérience s'est, elle aussi, soldée par un échec complet. Le 4ème jour, tous les oeufs étaient morts.

Essai n° 3, en 1962, à la Sisaony :

- 3 lots de 100 oeufs chacun ont été mis dans les étangs n° 14, 15 et 26. Au départ, on notait très peu d'oeufs blancs.

Les éclosions ont eu lieu les 24 et 25 octobre 1962.

Le comptage effectué le 10 novembre 1962 (alevins de 16 à 17 jours) donne les résultats suivants :

n° 14	44 alevins
n° 15	6 alevins
n° 26	22 alevins

Les pourcentages d'alevins obtenus dans les 3 petits étangs sont faibles avec une moyenne de l'ordre de 24 pour cent de survie au bout de 16 à 17 jours.

Essai n° 4, en 1962, à la Sisaony :

- 3 lots de 100 oeufs chacun sont placés dans les étangs n° 14, 15 et 26.

Le comptage des oeufs blancs a lieu le jour de la ponte, soit le 16 novembre, et on obtient :

n° 14 (25 m^2)	100 oeufs	27 bons	73 blancs	73 pour cent en moyenne d'oeufs blancs
n° 15 (20 m2)	100 oeufs	18 bons	82 blancs	
n° 26 (75 m^2)	100 oeufs	36 bons	64 blancs	

Le grand nombre d'oeufs blancs constaté vient peut-être de l'insuffisance de la laitance fournie par les deux jeunes mâles (sujets de 2 ans).

Le comptage des alevins effectué le 4 décembre 1962 (alevins de 14-15 jours) donne

n° 14	1 alevin	donc taux de production voisin de 4 pour cent au bout de 15 jours.
n° 15	9 alevins	
n° 26	2 alevins	

Essai n° 5, en 1962, à la Sisaony :

- 3 éléments de 100 oeufs chacun sont placés dans les 3 petits étangs d'éclosion n° 14, 15 et 26.

L'éclosion a eu lieu les 18 et 19 décembre 1962.

Le 7 janvier 1963 a lieu le comptage des alevins qui donne :

n° 14 : 3 pour cent d'oeufs blancs au départ .... 15 alevins
n° 15 : 4 pour cent d'oeufs blancs au départ .... 7 alevins
n° 26 : 7 pour cent d'oeufs blancs au départ .... 0 alevin

Le taux de survie des alevins est donc d'environ 7% ce qui est très faible. Ceci ne peut être dû qu'à l'action très intensive des prédateurs dans les petits étangs.

Essai n° 6, en 1962, à Ampamaherana :

Le 21 décembre 1962, 4 lots de 100 oeufs chacun environ sont placés dans les étangs F-18, F-19, F-20 et F-21 de 4 m^2 chacun.

Le comptage fait à des dates échelonnées donne les résultats suivants:

F-18	F-19	F-20	F-21
100 oeufs fécondés	100 oeufs fécondés	110 oeufs fécondés	110 oeufs fécondés
4 oeufs non féc.	3 oeufs non féc.	5 oeufs non féc.	6 oeufs non féc.
104 oeufs	103 oeufs	115 oeufs	116 oeufs
26/12/62 : 17 alev.	2/1/63 : 23 alev.	9/1/63 : 26 alev.	16/1/63 : 14 alev.
17 pour cent oeufs fécondés	23 pour cent oeufs fécondés	23,6 pour cent oeufs fécondés	12,7 pour cent oeufs fécondés

Les taux de survie sont donc, dans l'ensemble, assez faibles, même s'ils sont en-dessous de la réalité, compte tenu des pertes au ramassage (surtout le 26 décembre 1962).

Par contre, il apparaît que le pourcentage des oeufs blancs non fécondés au départ est faible.

Les alevins obtenus sont en nombres plus faibles que ceux obtenus dans des expériences semblables à Ampamaherana en 1961-1962 (voir page 12). De même les oeufs blancs sont beaucoup moins nombreux que ceux observés en 1961-1962.

Compte tenu des alevins qui ne sont pas pêchés, il semble qu'il faille bien admettre un pourcentage d'alevins vivant le 14ème jour après l'éclosion qui soit voisin de 23 pour cent des oeufs pondus (fécondés ou non), ce pourcentage n'étant qu'un ordre de grandeur mais qui fixe néanmoins les idées sur les superficies à donner aux étangs d'éclosion et de grossissement.

Essai n° 7, en 1963, à Ampanaherana :

A partir de 1963, pour mieux préciser l'action des prédateurs, nous avons poursuivi les essais de comptage en plaçant les oeufs dans de petites caisses cubiques garnies de grillage moustiquaire et doublées d'une toile fine de coton (Soga). Pour cette expérience, nous avons utilisé 4 caisses cubiques de 0,40 m de côté qui contiennent chacune environ 110 oeufs. Les comptages d'alevins sont effectués le jour d'éclosion, le 7ème, le 14ème et le 21ème jour après l'éclosion.

Deux femelles respectivement de 2,200 kg et de 2,400 kg ont été utilisées.

Voici d'ailleurs les tableaux concernant ces expériences :

1°- Femelle pesant 2,200 kg : étang B-44, ponte le 17/10/1963

Caisse n° 1

Mise en place le 17/10/63
Nbre de bons oeufs 103
Nbre d'oeufs blancs 8
Apparition d'alevins 21/10/63
Date de récolte 21/10/63
Total d'alevins 67
Le jour de l'éclosion, soit 65% des oeufs fécondés.

Caisse n° 2

Mise en place le 17/10/63
Nbre de bons oeufs 105
Nbre d'oeufs blancs 5
Apparition d'alevins 21/10/63
Date de récolte 28/10/63
Total d'alevins 75
Le 7ème jour après l'éclosion, soit 71,4% des oeufs fécondés.

Caisse n° 3

Mise en place le 17/10/63
Nbre de bons oeufs 102
Nbre d'oeufs blancs 7
Apparition d'alevins 21/10/63
Date de récolte 4/11/63
Total d'alevins 80
Le 14ème jour après l'éclosion, soit 78,4% des oeufs fécondés.

Caisse n° 4

Mise en place le 17/10/63
Nbre de bons oeufs 100
Nbre d'oeufs blancs 9
Apparition d'alevins 21/10/63
Date de récolte 11/11/63
Total d'alevins 66
Le 21ème jour après l'éclosion, soit 66% des oeufs fécondés.

2°- Femelle pesant 2,400 kg : étang B-44, ponte le 26/11/63

Caisse n° 1

Mise en place le 26/11/63
Nbre de bons oeufs 103
Nbre d'oeufs blancs 6
Apparition d'alevins 30/11/63
Date de récolte 30/11/63
Total d'alevins 77
Le jour de l'éclosion, soit 74,7% des oeufs fécondés.

Caisse n° 2

Mise en place le 26/11/63
Nbre de bons oeufs 105
Nbre d'oeufs blancs 5
Apparition d'alevins 30/11/63
Date de récolte 7/12/63
Total d'alevins 81
Le 7ème jour après l'éclosion, soit 77,1% des oeufs fécondés.

Caisse n° 3

Mise en place le 26/11/63
Nbre de bons oeufs 104
Nbre d'oeufs blancs 5
Apparition d'alevins 30/11/63
Date de récolte 14/12/63
Total d'alevins 63
Le 14ème jour après l'éclosion, soit 60,5% des oeufs fécondés.

Caisse n° 4

Mise en place le 26/11/63
Nbre de bons oeufs 106
Nbre d'oeufs blancs 4
Apparition d'alevins 30/11/63
Date de récolte 21/12/63
Total d'alevins 79
Le 21ème jour après l'éclosion, soit 74,5% des oeufs fécondés

Ces deux tableaux nous montrent que :

a) Le nombre d'alevins obtenus à partir d'une moyenne de 110 oeufs est important puisque nous avons une moyenne de 73 alevins par caisse avec les 2 femelles. Ceci nous donne un pourcentage de réussite de l'ordre de 66 pour cent à l'abri des prédateurs, ce qui est très intéressant.

A titre de comparaison rappelons que les alevins bons à être distribués obtenus à partir des 4 femelles de carpe royale dont les pontes ont fait l'objet de comptages (voir page 4), sont au nombre de 8.440, 9.065, 7.830 et 5.840 ce qui donne un pourcentage de 8,7, 9,3, 8,7 et 7,4 par rapport aux oeufs fécondés.

Ceci suffit à montrer les énormes dégâts que causent les prédateurs puisque la population d'alevins bons à être distribués n'atteint même pas 10% des oeufs fécondés.

b) C'est le 7ème jour d'éclosion que le nombre d'alevins vivants (moyenne 78) est le plus important, ceci est explicable du fait que les phénomènes de resserrement des alevins ne jouent pas encore. C'est vraisemblablement à cause de cela que le nombre d'alevins est plus faible (moyenne 72) aux 14ème et 21ème jour après l'éclosion.

Essai n° 8, en 1964, à Ampamaherana :

A partir de 1964, toutes les expériences de comptage d'alevins éclos à l'abri des prédateurs se font dans de grandes caisses de 0,900 m^3 (1,50 m x 1 m x 0,60 m) garnies de grillage moustiquaire doublé d'une fine toile de coton (Soga). Dans chacune de ces caisses, on peut mettre un balai entier (60 dm^2), ce qui nous rapproche des conditions normales d'éclosion et ce qui peut théoriquement permettre une production importante d'alevins.

Comme dans le cas des essais précédents, les comptages s'effectuent le jour de l'éclosion, le 7ème jour, le 14ème et le 21ème jour après l'éclosion.

Après 21 jours, les alevins sont supposés devoir être assez forts pour être définitivement à l'abri des prédateurs.

La nourriture distribuée quotidiennement consiste en un jaune d'oeuf cuit et soigneusement écrasé.

Les résultats de cet essai sont indiqués ci-dessous :

1ère expérience : 4 balais provenant de la 1ère pose.

Etang B-21 29/9/64 : caisse n° 1 (1er jour) 5/10/64 : éclosion 5/10/64 : comptage : 6.563 alevins de 5mm	Etang B-22 29/9/64 : caisse n° 2 (7ème jour) 5/10/64 : éclosion 12/10/64 : 5.732 alevins de 5 mm
Etang B-21 29/9/64 : caisse n° 3 (14ème jour) 5/10/64 : éclosion 19/10/64 : comptage: 4.235 alevins de 8 mm	Etang B-22 29/9/64 : caisse n° 4 (21ème jour) 5/10/64 : éclosion 26/10/64 : 2.941 alevins de 8 mm

Il est à noter que le chiffre obtenu dans la caisse n° 3 est un peu faussé du fait qu'une paroi de cette caisse a été percée en cours d'expérience.

Cependant, les résultats acquis sont très intéressants.

On constate en effet, que le nombre d'alevins produits à partir d'un balai est très élevé quand l'éclosion se fait à l'abri des prédateurs.

Le nombre d'alevins diminue régulièrement d'une semaine à l'autre, ce qui est normal, puisque, de toutes manières, il faut compter avec la mortalité naturelle.

Cependant, au 21ème jour, il y a encore près de 3.000 alevins dans la caisse n° 4 et il ne faut pas perdre de vue qu'un balai ne représente, en moyenne, que le 1/12ème de la ponte d'une femelle.

Malheureusement, malgré la distribution de jaune d'oeuf, les alevins, bien que vigoureux, restent très petits par manque d'espace vital et, sans doute, du fait du manque de nourriture naturelle.

D'ailleurs, le jaune d'oeuf aurait pu être mieux utilisé si, avant d'être distribué simplement écrasé, il avait été délayé, au préalable, dans un récipient contenant de l'eau légèrement tiède.

En effet, simplement écrasé, le jaune d'oeuf se désagrège mal dans l'eau des étangs et les très jeunes alevins ont probablement du mal à absorber des parcelles qui, dans le tout jeune âge, doivent leur paraître grossières.

Une partie de la nourriture artificielle distribuée est donc restée inutilisée.

Après les comptages, les alevins ont été mis dans des étangs de grossissement où ils ont subi des pertes voisines de 40 à 50 pour cent avant le contrôle définitif.

Remarque : Les 8 balais de la 1ère pose placés en étangs dans les conditions d'éclosion normale n'ont donné, au total, que 627 alevins.

2ème expérience : 2ème pose.

<table>
<tr>
<td>B-25 : caisse n° 1
20/10/64 : ponte
26/10/64 : éclosion et comptage, 3.600 alevins de 5 mm</td>
<td>B-25 : caisse n° 2
20/10/64 : ponte
26/10/64 : éclosion
2/11/64 : comptage : 2.650 alevins de 5 mm</td>
</tr>
<tr>
<td colspan="2">B-24 : caisse n° 3
20/10/64 : ponte
résultat : néant
Hypothèse : Il est possible que les mâles n'aient pas répandu leur laitance sur tous les balais.</td>
</tr>
</table>

A noter que la caisse n° 4 n'a pu être utilisée pendant cette deuxième expérience car elle était encore occupée par les alevins du premier essai. Néanmoins, cette expérience donne sensiblement les mêmes indications que la précédente avec des nombres d'alevins encore élevés bien que nettement inférieurs à ceux obtenus à partir de la 1ère pose.

Les remarques que l'on peut faire sont les mêmes que celles faites pour la première expérience.

Remarque : Les 9 balais de la 2ème pose placés en étangs dans les conditions d'éclosion normale n'ont donné, au total, que 850 alevins.

Essai n° 9, en 1964, à Périnet :

Le 17 octobre 1964, 4 balais sont transférés dans 4 caisses exactement semblables à celles utilisées à Ampamaherana et placées pour éclosion dans les étangs F-5, F-6, F-7 et F-8.

Le 21 octobre 1964, il y a apparition d'alevins.

Dans F-5, le comptage a lieu le 22 octobre 1964 et on trouve 3.886 alevins.
Dans F-6, le comptage a lieu le 28 octobre 1964 et on trouve 2.900 alevins.
Dans F-7, le comptage a lieu le 4 novembre 1964 et on trouve seulement 926 alevins.
Dans F-8, le comptage a lieu le 11 novembre 1964 et on trouve 2.221 alevins.

Donc, à part le résultat aberrant du 4 novembre 1964, les chiffres obtenus sont analogues à ceux d'Ampamaherana, peut-être un peu plus faibles.

La diminution est régulière, mais le nombre d'alevins reste tout de même élevé le 21ème jour.

A Périnet comme à Ampamaherana, la croissance des alevins nés en caisse a été ralentie malgré une distribution de jaune d'oeuf chaque jour.

5.22 Conclusions

De l'examen de tous les essais qui viennent d'être relatés, il résulte que l'action importante des prédateurs se confirme très nettement.

Pour les pontes non protégées en étang, nous avons vu que, dans les meilleurs cas, le nombre d'alevins n'atteignait, au maximum, que 42,5 pour cent des oeufs fécondés.

Si l'éclosion se fait dans les caisses, le pourcentage s'élève à 66 pour cent.

Les comptages effectués dans de grandes caisses indiquent qu'un balai (c'est-à-dire le 1/12ème de la ponte totale) produit couramment plusieurs milliers d'alevins.

Dans le cas de l'éclosion en caisse, il reste encore une difficulté à vaincre : celle du grossissement normal des alevins; ceci afin qu'ils soient suffisamment robustes quand, vers l'âge de 21 jours, ils sont déversés en eau libre.

Sous cette réserve, il apparaît nettement que, grâce à ces essais, l'importance du facteur prédation a bien été mise en lumière. Il est désormais certain que dans la production des alevins en station, nous devons y attacher une grande importance et essayer de lutter efficacement contre lui.

6 CONCLUSION

La reproduction de la carpe en station présente encore bien des aspects inconnus et les techniques qui permettraient à coup sûr d'obtenir de bons rendements sont encore loin d'avoir été mises au point.

De nombreuses femelles mises en présence de mâles ne pondent pas et nous pensons actuellement que ces difficultés sont en relation avec le phénomène de l'ovogénèse qui, pour des raisons que nous ignorons mais que nous pensons pouvoir attribuer à des questions de nourriture, n'aboutit pas toujours à la formation d'un stock normal d'oeufs mûrs, aptes à être expulsés et fécondés.

Dans tous les cas, les quantités d'oeufs pondus sont inférieures à celles habituellement observées en Europe.

Il s'agit donc, quand il y a ponte, d'essayer de sauver au maximum les alevins qui éclosent et de les protéger dans leur jeune âge.

De ce point de vue, nous sommes en mesure de préconiser un certain nombre de mesures pratiques :

Pour favoriser les conditions de la ponte et de l'incubation, il y a lieu d'admettre dans la frayère une eau aussi propre que possible et d'éviter au maximum les boues en suspension.

Pour protéger les alevins, il ne faut pas hésiter à lutter par tous les moyens contre les prédateurs : larves d'insectes, insectes adultes, poissons voraces, oiseaux, etc.

En outre, il serait souhaitable de pouvoir faire éclore et grossir les alevins à l'abri complet des prédateurs : système des caisses par exemple.

Enfin, il faut améliorer les eaux des piscicultures à carpe et particulièrement celles des étangs d'éclosion et de grossissement en n'hésitant pas à traiter le fond des étangs comme des champs de culture : labour, aération des sols, enherbement naturel ou provoqué, apport de fumier, de chaux, d'engrais, dans le but de développer la nourriture naturelle favorable à la croissance des alevins.

Concernant l'ovogénèse, nous ne savons pas très bien comment favoriser ce phénomène. Cependant, on peut toujours recommander de donner le maximum de place aux reproducteurs pendant leur stockage avant la période de reproduction et de leur distribuer une nourriture aussi variée que possible.

Une question importante à résoudre dans les eaux tropicales serait aussi celle de la production maximum de zooplancton toujours présent dans les étangs, mais en quantité presque négligeable.

Etant donné la nature chimique des eaux des 3 stations considérées, il est difficile de lutter contre certains facteurs défavorables tels que la présence d'hydroxyde de fer qui risque de nuire à la bonne incubation des oeufs.

Il nous est également difficile d'intervenir sur le comportement des spermatozoïdes qui semble être intimement lié à la présence dans l'eau de certains sels dissous.

Malgré tout, nous pensons que, dans cette vaste question de la reproduction de la carpe, nous avons dès maintenant certaines possibilités d'intervenir très utilement pour aboutir à des productions intéressantes d'alevins, quitte à continuer à améliorer nos techniques au fur et à mesure que nos connaissances progresseront.

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8 ANNEXE

Situation et caractéristiques des stations

1. Station de la Sisaony
Km 24 sur la route Tananarive - Antsirabe
Sous-préfecture Tananarive-banlieue
Latitude : 19°. Altitude : 1.250 m

IV/E-3

Nombre et surface des étangs utilisés pour la carpiculture en 1962-1963 :
25 étangs. Total : 5.335 m^2
Analyse chimique des eaux (voir ci-dessous)
Température moyenne annuelle des eaux en 1961 : 22°4

2. **Station d'Ampamaherana**
A 35 km environ à l'Est de Fianarantsoa sur la voie ferrée Fianarantsoa-Manakara.
Sous-préfecture Fianarantsoa
Latitude : 21°29. Altitude : 1.060 m
Nombre et surface des étangs utilisés pour la carpiculture en 1962-1963 :
46 étangs. Total : 7.138 m^2
Analyse chimique des eaux (voir ci-dessous)
Température moyenne annuelle des eaux en 1961 : 21°6

3. **Station d'Analamazaotra-Périnet**
Au km 145 de la route Tananarive-Tamatave
Sous-préfecture de Moramanga
Latitude : 18°56. Altitude : 928 m
Nombre et surface des étangs utilisés pour la carpiculture en 1962-1963 :
12 étangs. Total : 5.290 m^2
Analyse chimique des eaux (voir ci-dessous)
Température moyenne annuelle de l'eau en 1961 : 23°8

Caractéristiques chimiques moyennes de l'eau des stations

Année	Extrait sec mg/l	Dureté		Matières organiques		pH	SBV
		totale en degrés	permanente en degrés	milieu acide mg/l	milieu acide mg/l		
		Station Sisaony (étang pisciculture)					
1955	130	5,4	4	4,89	14,82	6,1	0,45
1956	85					6,4	0,4
		Station d'Ampamaherana (étang de pisciculture)					
1955	160	1,96	1	3,72	3,23	6,5	0,4
1956	48			4,4	0,8	5	0,28
		Station d'Analamazaotra (étang de pisciculture)					
1955	60	1,45	0,95	2,56	2,24	6,05	
1956	44			8,96	2,96	6,8	0,47

Analyse échantillons d'eau

Stations	Résistivité en Ohms		SBV	pH
	cm (20°C)	à différentes températures		
Analamazaotra	28 800	29°C 24 400	0,2	6,6
	24 400	31°C 18 500	0,3	6,3
	24 400	31°C 18 500	0,5	6,6
Ampamaherana	36 400	31°C 42 000	0,4	5,5

Analyses d'eau

Rivière Analamazaotra dans la station Périnet

Résidu après évaporation : 75 mg/l.
Résidu après calcination : 24 mg/l.
Déperdition à la calcination : 51 mg/l.

NH_4	: 0,00mg/l	Ca	: 0,28° DH
NO_2	: 0,00mg/l	Mg	: 0,0° DH
NO_3	: 0,0 mg/l	Fe-tot.	: 0,15mg/l
N-tot.	: 0,0mg/l	Cl	: 3,5 mg/l
O_2	: 7,92mg/l (17°4 C),SBV:0,5	pH	: 6

Rivière Ampamaherana près la station

Résidu après évaporation : 47 mg/l.
Résidu après calcination : 10 mg/l.
Déperdition à la calcination : 37 mg/l.

NH_4	: 0,17mg/l	Ca	: 0,42° DH
NO_2	: 0,00mg/l.	Mg	: 0,0° DH
NO_3	: 0,0 mg/l	Fe-tot.	: 0,25mg/l
N-tot.	: 0,0 mg/l	Cl	: 0,0 mg/l

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IV/E-4

ETUDE SUR LA REPRODUCTION A MADAGASCAR DE COUPLES DE DIFFERENTES ESPECES DE TILAPIA

par

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TABLE DES MATIERES

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Résumé

De 1962 à 1964, nous avons entrepris, à Madagascar, dans une station d'altitude située à 35 km à l'Est de Fianarantsoa, celle d'Ampamaherana, une série d'expériences destinées à préciser les conditions de reproduction de diverses espèces de Tilapia.

Ces expériences nous ont permis de constater :

- qu'à plus de 1.000 m d'altitude, il y a un arrêt complet de la fonction de reproduction de début mai à fin octobre,
- que Tilapia zillii, seule espèce herbivore mise en observation est bien plus prolifique que les espèces de Tilapia microphages planctonophages Tilapia macrochir, T. mossambica et T. nilotica,
- qu'enfin, les frais de pleine saison chaude : novembre, décembre, janvier, sont ceux qui donnent le plus grand nombre d'alevins.

STUDY ON REPRODUCTION OF DIFFERENT SPECIES OF TILAPIA IN MADAGASCAR

Abstract

Between 1962 and 1964 at the high elevation Ampamaherana Pisciculture Station, 35 km east of Fianarantsoa, Madagascar, a series of experiments were conducted to determine the requisites for the propagation of various species of *Tilapia*. Based on the results obtained we can make the following conclusions:

- at over 1,000 m elevation, reproduction ceases completely from the beginning of May to the end of October;

- *Tilapia zilli*, the only herbivorous species under observation, is much more prolific than the microphagous and planktonophagous *Tilapia macrochir*, *T. mossambica* and *T. nilotica*;

- spawnings during the hot season, November, December and January, give the largest number of fry.

ESTUDIO SOBRE LA REPRODUCCION EN MADAGASCAR DE PAREJAS DE DIFERENTES ESPECIES DE TILAPIA

Extracto

De 1962 a 1964 se han realizado en Madagascar, en la estación de altura Ampamaherana situada a 35 km al este de Fianarantsoa, una serie de experiencias destinadas a precisar las condiciones de reproducción de diversas especies de *Tilapia*.

Estas experiencias han permitido comprobar:

- que a más de 1000 m de altitud, hay una detención completa de la función de reproducción desde principios de mayo a fines de octubre,

- que *Tilapia zillii*, única especie herbívora puesta en observación, es mucho más prolífera que las especies de *Tilapia* micrófagas planctófagas *Tilapia macrochir*, *T. mossambica* y *T. nilotica*,

- finalmente, las frezas de plena estación cálida (noviembre, diciembre, enero) son las que dan el número mayor de alevines.

IV/E-4

1 CONDITIONS DE L'EXPERIENCE

A Ampamaherana, station située à 35 km environ à l'Est de Fianarantsoa et à une altitude de 1.060 m, nous avons entrepris, en août 1962, une expérience sur la reproduction des couples de Tilapia zillii, T. mossambica, T. macrochir et T. nilotica.

Pour chaque espèce, nous avons utilisé deux couples et chacun des couples a été placé dans un étang de un are.

Les reproducteurs étaient de très petite taille puisque, au début de l'expérience, leurs poids s'échelonnaient entre 50 et 100 g seulement.

Les observations ont pris fin après deux saisons de reproduction en juillet 1964.

2 RESULTATS OBTENUS

Ces résultats sont donnés par les 5 tableaux numérotés de I à V.

L'examen des tableaux I à IV montre d'abord qu'il y a un arrêt complet de la reproduction de fin avril - début mai, à la fin octobre.

Ce sont les Tilapia herbivores : cas du Tilapia zillii, qui donnent de loin la plus grande production d'alevins.

Cette grande prolificité résulte à la fois d'un nombre de frais élevé et d'une moyenne d'alevins par frai supérieure à ce qu'on trouve chez les autres espèces.

Les espèces de Tilapia microphages planctonophages (mouth breeder) ont une résilience assez faible.

Chez les trois espèces considérées, le nombre de frais est moins important que celui observé pour Tilapia zillii mais c'est surtout la moyenne d'alevins par frai qui est bien plus faible.
Dans le cas de la station d'Ampamaherana, c'est Tilapia macrochir qui semble être le moins prolifique derrière Tilapia mossambica et Tilapia nilotica et ceci résulte surtout du nombre moyen d'alevins par frai particulièrement faible chez Tilapia macrochir.

Les résultats enregistrés lors de la deuxième saison de reproduction, c'est-à-dire en 1963-1964, sont meilleurs que ceux obtenus en 1962-1963; mais ceci est assez normal du fait que les reproducteurs ont grandi de 1962 à 1963.

On peut noter, en particulier, que le nombre total d'alevins produits par chaque espèce est plus élevé en 1963-1964 qu'en 1962-1963, à condition de considérer l'absence de reproduction du deuxième couple de Tilapia nilotica en 1963-1964 comme un accident.

Durant la deuxième saison, la moyenne d'alevins par frai est également plus forte sauf en ce qui concerne Tilapia zillii mais cette espèce a donné davantage de frais en 1963-1964 qu'en 1962-1963.

Un dernier fait qui semble se dégager des résultats obtenus, c'est que, pour toutes les espèces de Tilapia considérées, le nombre d'alevins par frai passe par un maximum en novembre, décembre, janvier et, qu'en général, le dernier frai de la saison est celui qui donne le minimum d'alevins.

Tableau I

Répartition des pontes par mois

Tilapia zillii

Premier couple : 1 mâle de 16 cm = 75 g
1 femelle de 14 cm = 50 g

Deuxième couple : 1 mâle de 16 cm = 100 g
1 femelle de 13 cm = 50 g

Premier couple				Deuxième couple			
Date	Mois	Nbre d'alevins	Total Total	Date	Mois	Nbre d'alevins	Total
12/11/62	Nov.	1.145	1.145	12/11/62	Nov.	1.050	1.050
11/12/62	Déc.	3.900	8.206	4/12/62	Déc.	8.073	8.073
26/12/62		4.306		24/12/62			
12/ 1/63	Janv.	3.720	7.860	22/ 1/63	Janv.	3.607	3.607
28/ 1/63		4.140		11/ 2/63	Fév.	3.908	3.908
6/ 3/63	Mars	1.360	1.360	28/ 3/63	Mars	1.324	1.324
12/ 4/63	Avril	980	980	22/ 4/63	Avril	950	950
			19.551				18.912
23/10/63	Oct.	1.600	1.600	12/11/63	Nov.	1.500	1.500
22/11/63	Nov.	1.800	1.800	4/12/63	Déc.	1.780	5.425
21/12/63	Déc.	2.376	2.376	26/12/63		3.645	
8/ 1/64	Janv.	4.590	8.410	10/ 1/64	Janv.	4.650	7.119
23/ 1/64		3.820		28/ 1/64		2.469	
8/ 2/64	Fév.	3.600	5.450	13/ 2/64	Fév.	2.322	4.277
25/ 2/64		1.850		28/ 2/64		1.955	
13/ 3/64	Mars	1.600	1.600	25/ 3/64	Mars	1.730	1.730
1/ 4/64	Avril	1.585	1.585	28/ 4/64	Avril	950	950
			22.821				21.001

Tableau II

Répartition des pontes par mois

Tilapia mossambica

Premier couple : 1 mâle de 18 cm = 100 g
1 femelle de 16 cm = 75 g

Deuxième couple : 1 mâle de 19 cm = 100 g
1 femelle de 16 cm = 75 g

Premier couple				Deuxième couple			
Date	Mois	Nbre d'alevins	Total	Date	Mois	Nbre d'alevins	Total
8/11/62	Nov.	217	217	14/11/62	Nov.	228	228
6/12/62	Déc.	626	626	3/12/62	Déc.	462	462
18/ 1/63	Janv.	598	598	7/ 1/63	Janv.	425	425
6/ 3/63 22/ 3/63	Mars	500 250	750	4/ 2/63	Fév.	388	388
4/ 4/63	Avril	225	225	6/ 3/63 22/ 3/63	Mars	350 210	560
			2.416				2.063
6/11/63	Nov.	1.124	1.124	4/11/63	Nov.	1.143	1.143
4/12/63 26/12/63	Déc.	1.272 1.435	2.707	3/12/63 21/12/63	Déc.	1.215 1.582	2.797
28/ 1/64	Janv.	1.350	1.350	31/ 1/64	Janv.	1.175	1.175
17/ 2/64	Févr.	1.221	1.221	10/ 2/64	Févr.	1.080	1.080
10/ 3/64	Mars	992	992	4/ 3/64	Mars	987	987
28/ 4/64	Avril	775	775				
			8.169				7.182

Tableau III

Répartition des pontes par mois

Tilapia nilotica

Premier couple : 1 mâle de 18 cm = 100 g
1 femelle 15 cm = 50 g

Deuxième couple : 1 mâle de 20 cm = 100 g
1 femelle 15 cm = 50 g

Premier couple				Deuxième couple			
Date	Mois	Nbre d'alevins	Total	Date	Mois	Nbre d'alevins	Total
20/11/62	Nov.	837	837	23/11/62	Nov.	985	985
11/12/62	Déc.	950	950	7/ 1/63	Janv.	608	608
11/ 1/63	Janv.	487	487	5/ 3/63	Mars	390	650
8/ 3/63	Mars	370	575	22/ 3/63		260	
28/ 3/63		205		22/ 4/63	Avril	210	210
			2.849				2.453
19/12/63	Déc.	965	965				
9/ 1/64	Janv.	1.021	1.021				
1/ 2/64	Fév.	985	985				
4/ 3/64	Mars	950	950				
13/ 4/64	Avril	835	835				
			4.756	Pas de reproductions pendant la saison de reproduction 1963 - 1964			

Tableau IV

Répartition des pontes par mois

Tilapia macrochir

Premier couple : 1 mâle de 14 cm = 50 g
1 femelle 14 cm = 50 g

Deuxième couple : 1 mâle de 18 cm = 100 g
1 femelle 14 cm = 50 g

Premier couple				Deuxième couple			
Date	Mois	Nbre d'alevins	Total	Date	Mois	Nbre d'alevins	Total
21/11/62	Nov.	309	309	22/11/62	Nov.	644	644
11/ 1/63	Janv.	406	406	28/ 1/63	Janv.	406	406
6/ 3/63	Mars	370	370	8/ 3/63	Mars	375	375
4/ 4/63	Avril	128	128	4/ 4/63	Avril	132	132
			1.213				1.557
12/11/63	Nov.	455	455	25/11/63	Nov.	550	550
20/12/63	Déc.	629	629	21/12/63	Déc.	721	721
10/ 1/64	Janv.	951	1.801	8/ 1/64	Janv.	975	1.925
28/ 1/64		850		31/ 1/64		950	
19/ 2/64	Fév.	613	613	6/ 3/64	Mars	575	575
23/ 3/64	Mars	545	545	14/ 4/64	Avril	550	550
4/ 5/64	Mai	428	428				
			4.471				4.321

3 CONCLUSION

Les résultats obtenus confirment ce que l'on sait déjà dans d'autres pays de la biologie de la reproduction chez les *Tilapia* : les *Tilapia* herbivores sont beaucoup plus prolifiques que les microphages planctonophages qui compensent cette infériorité en prenant beaucoup plus soin de leurs alevins.

A Madagascar, en station d'altitude, où la saison froide est bien marquée, il y a un net arrêt des fonctions de reproduction qui dure près de 6 mois dans le cas de la station considérée.

Tableau V

Résultats comparatifs

Espèces	Total d'alevins produits par 2 couples	Nombre de frais pour 2 couples	Nombre moyen de frais par couple	Nombre moyen d'alevins par frai	Nombre maximum d'alevins par frai	Nombre minimum d'alevins par frai
T. zillii	88.285	32	16	2.571	4.690	950
T. mossambica	19.830	25	12	791	1.582	210
T. nilotica(1)	10.058			670	1.021	205
T. macrochir	11.562	21	10	550	975	128

(1) L'absence de reproduction pour le deuxième couple de *T. nilotica* en 1963-1964, semble résulter d'un accident; c'est pourquoi nous n'avons pu tenir compte du nombre total de frais ni du nombre moyen de frais par couple pour cette espèce.

****

IV/E-5

ESSAIS D'HYBRIDATION DANS LE GENRE TILAPIA A LA STATION DE RECHERCHES PISCICOLES DE BOUAKE, COTE D'IVOIRE

par

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ESSAIS D'HYBRIDATION DANS LE GENRE TILAPIA A LA STATION DE RECHERCHES PISCICOLES DE BOUAKE, COTE D'IVOIRE

Résumé

Pour constituer des élevages monosexes de mâles, des essais d'hybridation ont été entrepris sur la Station de Bouaké depuis 1961.

L'obtention des hybrides mâle T. nilotica x femelle T. macrochir est facile et régulière à raison de 500 hybrides environ par couple. La proportion des sexes est constante: mâles 75 pour cent, femelles 25 pour cent. La croissance des hybrides est à peine supérieure à celle des espèces parentes mais celle des mâles est beaucoup plus rapide que celle des femelles. Les hybrides sont fertiles mais l'élevage de F_2 ne présente pas d'intérêt. Neuf élevages de back-cross (avec femelle T. nilotica) sont en cours.

L'obtention des hybrides mâle T. macrochir x femelle T. nilotica est très irrégulière et le nombre des hybrides obtenus est de 500 par couple également. Les hybrides sont tous des mâles. La croissance individuelle moyenne est voisine de celle du croisement précédent. Les hybrides sont fertiles mais les deux back-cross réalisés n'ont apporté aucun élément intéressant.

Dans le croisement mâle T. zillii (local) x femelle T. zillii (Congo), la reproduction est régulière et abondante, mais les hybrides paraissent sans intérêt.

Dans le croisement male T. zillii (Congo) x femelle T. zillii (local), la reproduction est régulière et abondante. Ces hybrides ne sont pas intéressants, sauf dans le cas d'un élevage où toutes les femelles étaient stériles.

HYBRIDIZATION OF THE GENUS TILAPIA AT THE FISH CULTURE RESEARCH STATION AT BOUAKE, IVORY COAST

Abstract

In order to produce mono-sexual (males only) stocks of fish, hybridization trials were started at the Bouaké station in 1961.

The hybrid male Tilapia nilotica x female Tilapia macrochir is easily obtained on a regular basis at the rate of about 500 hybrids per couple. The proportion of sexes is constant: males 75 percent, females 25 percent. The rate of growth of the hybrids is just barely higher than in the parent species, the males growing much more quickly than the females. These hybrids are fertile but there is no particular point in raising the F_2 generation. Nine back-cross generations (with the female T. nilotica) are being raised.

The hybrid male T. macrochir x female T. nilotica can only be obtained irregularly, also at the rate of about 500 per couple. These hybrids are all males. The average rate of growth of individuals is close to that of the preceding cross. The hybrids are fertile but two back-crosses that were obtained are of no particular value.

In the cross male T. zillii (local) x female T. zillii (Congo), propagation is regular and abundant although the hybrids are of no particular value.

In the cross male T. zillii (Congo) x female T. zillii (local), propagation is regular and abundant. These hybrids are of no particular value except in one case in which all the females were sterile.

IV/E-5

ENSAYOS DE HIBRIDACION EN EL GENERO TILAPIA EN LA ESTACION DE INVESTIGACIONES PISCICOLAS DE BOUAKE, COSTA DE MARFIL

Extracto

Para efectuar la cría monosexual de machos, se han realizado ensayos de hibridación en la Estación de Bouaké desde 1961.

La obtención de los híbridos machos, *T. nilotica* x hembras *T. macrochir* es fácil y regular a razón de 500 híbridos, aproximadamente, por pareja. La proporción de sexos es constante: machos, 75%, hembras, 25%. El crecimiento de los híbridos es apenas superior al de las especies progenitoras, pero el de los machos es mucho más rápido que el de las hembras. Los híbridos son fértiles pero la cría de F_2 no presenta interés. Están en curso nueve crías de retrocruza (con hembra *T. nilotica*).

La obtención de los híbridos macho *T. macrochir* x hembra *T. nilotica* es muy irregular y el número de los obtenidos es igualmente de 500 por pareja.

Los híbridos son todos machos.

El crecimiento individual medio está próximo al del caso precedente.

Los híbridos son fértiles pero las dos retrocruzas realizadas no han aportado ningún elemento interesante.

El cruzamiento macho *T. zillii* (local) x hembra *T. zillii* (del Congo): la reproducción es regular y abundante pero los híbridos parecen no presentar interés.

El cruzamiento macho *T. zillii* (del Congo) x hembra *T. zillii* (local): la reproducción es regular y abundante. Estos híbridos no son interesantes, salvo en el caso de una cría en que todas las hembras eran estériles.

1 BUTS DES ESSAIS

En étangs de pisciculture, dans les régions tropicales à température constamment élevée, les diverses espèces de Tilapia commencent à se reproduire à une très faible taille et fournissent des pontes répétées à quelques semaines d'intervalle. Les étangs sont ainsi rapidement surpeuplés en jeunes sujets et l'obtention d'une production intéressante de poissons de consommation de taille suffisante est rendue pratiquement difficile.

On a, depuis longtemps, songé, pour pallier cet inconvénient, à pratiquer des élevages monosexes spécialement avec des mâles dont la croissance est généralement meilleure que celle des femelles.

Mais la méthode monosexe exige un élevage préalable assez long (4 à 6 mois)[1] d'alevins des deux sexes avant de pouvoir déterminer et trier dans de bonnes conditions pratiques les mâles qui seront seuls utilisés dans l'élevage proprement dit. Le triage est ennuyeux et comporte des risques d'erreurs même avec du personnel entraîné. Les femelles restent inutilisées.

L'obtention directe d'hybrides tous mâles grâce à des croisements entre espèces ou variétés régionales de Tilapia est donc susceptible de présenter un gros intérêt. Un tel résultat a été obtenu en Malaisie (Hickling, 1960) en croisant deux variétés de T. mossambica. Les hybrides obtenus ont montré en outre une rapidité de croissance très supérieure à celle des parents (Hickling, 1959).

Nous avons entrepris à la Station de Pisciculture de Bouaké divers essais d'hybridation en vue de rechercher si des résultats analogues pourraient être obtenus par des croisements entre les espèces ou variétés régionales de Tilapia actuellement utilisées dans la pisciculture africaine.

2 ESPECES UTILISEES

Nous disposions:

- en ce qui concerne les espèces de Tilapia à incubation buccale et microphages, d'un stock de T. macrochir introduits à la Station en 1958 depuis le Cameroun où ils avaient été eux-mêmes importés du Katanga et d'un stock de T. nilotica originaires du Bassin de la Volta Noire (Mare aux Hippos).
- en ce qui concerne les espèces de Tilapia ne pratiquant pas l'incubation buccale et herbivores, de deux stocks de T. zillii, l'un originaire de Côte d'Ivoire, l'autre du Congo (Yangambi).

Les sujets appartenant à ces deux stocks diffèrent très peu mais ils se distinguent aisément et le personnel de la Station de Bouaké les trie sans difficulté. Les T. zillii congo ont un nombre de rayons plus élevé aux nageoires dorsale et anale et une moyenne vertébrale supérieure (Daget, 1960).

Nous avons réalisé les croisements suivants :

Mâle T. nilotica avec femelle T. macrochir,
Mâle T. macrochir avec femelle T. nilotica,
Mâle T. zillii local avec femelle T. zillii Congo,
Mâle T. zillii Congo avec femelle T. zillii local.

---

[1] Du moins chez les espèces utilisées en Afrique de l'Ouest (T. nilotica, T. macrochir, T. zillii). Pour T. nigra, Brown et Van Someren (1953), estiment que la détermination des sexes est possible à partir de 2 à 3 mois lorsque les poissons atteignent 5 cm de longueur.

3 CROISEMENT MALE T. NILOTICA AVEC FEMELLE T. MACROCHIR

3.1 Obtention des hybrides F_1

a) Deux couples de géniteurs ont été mis en place le 6.12.60 dans deux étangs de 50 m2.

Couple A : mâle de 960 g, femelle de 410 g
1ère ponte constatée: le 16.1.61
2ème ponte constatée: le 27.2.61

Couple B : mâle de 980 g, femelle de 420 g
1ère ponte constatée le 27.2.61

Par suite de difficultés dûes à une sécheresse exceptionnelle, cet essai a dû être interrompu.

b) L'expérimentation a été reprise en octobre 1962 et poursuivie jusqu'en juillet 1963 avec 3 couples de géniteurs déposés dans 3 étangs de 50 m2. Les mâles pesaient de 800 à 900 g, les femelles de 200 à 300 g.

Le nombre d'hybrides obtenus a été le suivant:

	Nombre d'hybrides récoltés		
	Le 21.1.63	Le 23.4.63	Le 3.7.63
Couple I	84	755	470
Couple II	50	658	535
Couple III	106	782	679

c) Enfin, deux groupes comprenant chacun 8 couples de reproducteurs (couples IV et couples V), ont été placés le 7 mars et le 8 avril 1963 dans deux étangs de 400 m2. Les mâles pesaient en moyenne 1.300 g, les femelles 335 g. Ils y ont été maintenus jusqu'au 4 juillet 1963.

4.656 hybrides ont été pêchés dans le premier étang le 16 mai, 1.944 dans le deuxième le 4 juillet.

Le croisement mâle T. nilotica avec femelle T. macrochir fournit donc facilement et régulièrement des hybrides et la production moyenne est de l'ordre de 500 hybrides par couple.

3.2 Proportion des sexes chez les hybrides F_1

Les hybrides fournis par les couples ou groupes de couples I, II, III, IV, et V, ont fait l'objet de quatre élevages. Les sexes ont été déterminés quand les poissons ont atteint de 30 à 40 g à un âge de 5 à 7 mois. Les résultats ont été les suivants :

	Nombre total d'hybrides	Mâles		Femelles	
		Nombre	%	Nombre	%
Elevage C	1.030	759	73,7	271	26,3
Elevage D	1.065	787	73,9	278	26,1
Elevage E	723	493	68,2	230	31,8
Elevage F	1.059	815	77	244	23

La proportion de mâles et de femelles est à peu près constante dans les quatre élevages et reste voisine de la proportion théorique:

mâles .... 75 pour cent
femelles ...... 25 pour cent

La descendance du croisement mâle T. nilotica avec femelle T. macrochir est donc constituée par une population hybride comprenant 3 fois plus de mâles que de femelles.

3.3 Croissance individuelle et production des hybrides F_1

Il n'a malheureusement pas été possible de faire, en les plaçant dans des conditions identiques, des élevages parallèles d'hybrides et de sujets des espèces parentes. Nous ne pouvons donc faire de comparaison précise entre les hybrides et les espèces parentes ni en ce qui concerne la croissance individuelle, ni en ce qui concerne la production totale en poids qu'ils peuvent fournir.

Nous pouvons indiquer que:

- une mise en charge de 2.143 hybrides pesant en moyenne 3 g dans un étang de 400 m2 a fourni, avec alimentation artificielle, au bout de un an, 884 sujets pesant en moyenne 93 g. Croissance individuelle moyenne: 7,5 g per mois. Production: 1.880 kg/ha/an (sans tenir compte des alevins nés en cours d'élevage)[1].

- une mise en charge de 1.944 hybrides pesant en moyenne 3,4 g dans un étang de 400 m2 a fourni, avec alimentation artificielle, au bout de 10 mois, 956 sujets pesant en moyenne 90 g. Croissance individuelle moyenne: 8,7 g par mois. Production: 2.370 kg/ha/an (sans tenir compte des alevins nés en cours d'élevage)[2].

---

[1] En effectuant des vidanges de contrôle, on a éliminé à deux reprises, au 6ème et au 8ème mois d'élevage, les alevins nés dans l'étang (4 kg, 120 la première fois, 4 kg, 550 la deuxième). Lors de la vidange définitive, en fin d'élevage, on en a trouvé 14 kg, 650.

[2] On a éliminé 3 kg, 550 d'alevins grâce à une vidange de contrôle au 6ème mois d'élevage. On en a trouvé 12 kg, 100 en fin d'élevage.

- avec 400 hybrides mâles âgés de un an, pesant en moyenne 100 g et élevée pendant 8 mois avec alimentation artificielle dans un étang de 400 m2, on a obtenu une croissance individuelle moyenne de 24 g par mois et une production de 2.800 kg/ha/an.

- avec 350 sujets (200 mâles et 150 femelles) également âgés de un an, pesant en moyenne 89 g et élevés pendant 5 mois et demi avec alimentation artificielle dans un étang de 400 m2, on a obtenu une croissance individuelle moyenne de 16 g par mois et une production de 1.625 kg/ha/an (sans tenir compte des alevins nés dans l'étang en cours d'élevage) [1].

La comparaison de ces résultats avec ceux obtenus antérieurement à la Station de Bouaké dans des élevages de _T. nilotica_ et _T. macrochir_, conduits dans des conditions assez voisines, ne permet pas de conclure à une supériorité des hybrides par rapport aux espèces parentales aux points de vue croissance individuelle et production. Une telle supériorité, si elle existe, ne doit pas, en tous cas, être importante.

La croissance des mâles chez les hybrides est beaucoup plus rapide que celle des femelles, ainsi que le montre le tableau suivant:

	Nombre total d'hybrides	Age	Mâles		Femelles	
			Nombre	Pds moyen (g)	Nombre	Pds moyen (g)
Elevage A	130	un an	93	604	37	281
Elevage D	635	10 mois	439	100	196	65
Elevage E	683	9 mois	473	94	210	56

3.4 Reproduction des hybrides F_1

Les hybrides sont fertiles. La précocité de leur reproduction est tout à fait comparable à celle des espèces parentes. Comme chez celles-ci, les premières pontes se produisent à 5 ou 6 mois.

Un élevage d'hybrides de 2ème génération (F_2)[2] effectué pendant 11 mois et demi dans un étang de 400 m2 avec alimentation artificielle a donné les résultats suivants:

mise en charge ....: 1.325 sujets de 10 g
récolte : nombre: mâles ....: 384
femelles ....: 355
poids moyen : ....mâles ....: 94 g
femelles ....: 75 g
production : 1.290 kg/ha/an (sans tenir compte des alevins F_3 nés en cours d'élevage).

---

[1] Ces alevins représentaient un poids total de 32 kg et une production de 1.745 kg/ha/an.

[2] Ces hybrides F_2 provenaient des pontes survenues au cours de l'élevage A de 130 hybrides F_1.

Dans la limite de confiance qu'il est permis d'accorder à un résultat unique, on constate:

- que la proportion des sexes chez les hybrides F_2 est voisine de l'unité,
- que la croissance individuelle moyenne et la production sont inférieures à celles des hybrides F_1,
- que la supériorité de croissance des mâles par rapport à celle des femelles est plus faible que chez les hybrides F_1.

3.5 Croisement des hybrides F_1 avec femelle *T. nilotica* (Back-cross).

Six couples (mâles de 310 à 340 g, femelles de 100 à 140 g), ont été déposés dans six étangs de 50 m2 le 27 novembre 1964 et trois autres couples (mâles de 420 à 490 g, femelles de 170 à 200 g) le 1er février 1965.

Les neuf couples s'étaient reproduits deux mois plus tard et ont donné de 600 à 1.600 alevins. L'un d'eux en a produit 2.639.

Ces alevins sont en cours d'élevage dans des étangs de 400 m2 afin de déterminer le pourcentage de mâles et de femelles.

4 CROISEMENT MALE T. MACROCHIR AVEC FEMELLE T. NILOTICA

4.1 Obtention des hybrides F_1

a) Deux couples de géniteurs ont été mis en place le 6.12.60 dans deux étangs de 50 m2.

Couple A : mâle de 660 g, femelle de 365 g

Couple B : mâle de 720 g, femelle de 405 g

Entre le 6.12.60 et le 19.4.61, date à laquelle, par suite de difficultés dues à une sécheresse exceptionnelle l'essai a dû être interrompu, seul le couple B s'est reproduit une seule fois, le 28.2.61. 4 hybrides ont été retrouvés à la vidange de l'étang le 19.4.61.

b) L'expérimentation a été reprise en mai 1962 et poursuivie jusqu'en juin 1964 avec trois couples de géniteurs déposés dans 3 étangs de 50 m2. Les mâles pesaient 370, 340 et 330 g et les femelles 180, 140 et 130 g.

Les couples I et II ne se sont pas reproduits.

Le couple III s'est reproduit deux fois seulement en 19 mois et a fourni:

446 hybrides, le 22.10.62
424 hybrides, le 1. 3.63

c) En mars 1963, deux groupes de 8 couples (couples IV) et 5 couples (couples V) ont été placés dans deux étangs de 400 m2 et y ont été maintenus jusqu'en décembre 1964.

Les mâles pesaient 550 g en moyenne, les femelles 590 g en moyenne.

Les couples IV ont fourni:

20 hybrides en novembre 1963
156 hybrides en mars 1964
296 hybrides en juin 1964
95 hybrides en septembre 1964.

Les couples V ont fourni:

113 hybrides en novembre 1963
158 hybrides en juin 1964

d) En juillet 1964, 3 couples (VI, VII et VIII) ont été placés dans 3 étangs de 50 m2 et y ont été maintenus jusque fin mai 1965.

Les mâles pesaient 445 et 425 g, les femelles 355 et 350 g.

Le couple VI a fourni : 785 hybrides le 7.12.64

Le couple VII a fourni:(591 hybrides le 9.12.64
(234 hybrides le 18.3.65

Le couple VIII ne s'est pas reproduit.

e) Aucune reproduction n'a été obtenue de deux groupes de couples (4 mâles et 6 femelles) mis en place dans deux étangs de 400 m2 le 19 décembre 1964.

L'obtention d'hybrides avec ce croisement est donc très irrégulière. Dans les étangs où un seul couple avait été placé, nous n'avons obtenu au maximum que deux reproductions successives. Le nombre d'alevins hybrides pêchés dans les étangs à plusieurs couples a presque toujours été plus faible que celui pêché dans les étangs à un seul couple où il s'établit en moyenne à 500.

4.2 Proportion des sexes chez les hybrides F_1

Cinq élevages d'hybrides fournis par les couples B, III, IV et V et portant sur un total de 1.159 sujets, ont montré que ces sujets étaient tous des mâles sans aucune exception.

Par contre, lors d'une hybridation accidentelle à la Station de Yaoundé (Cameroun) où une femelle T. nilotica[1] s'est trouvée en présence de 10 mâles T. macrochir Bard (1960) , a constaté la présence de 107 mâles et 90 femelles hybrides dans une seule reproduction.

4.3 Croissance individuelle et production des hybrides F_1

Là encore, il n'a pas été possible de faire, en les plaçant dans des conditions identiques, des élevages parallèles d'hybrides et de sujets des espèces parentes.

Mais deux élevages d'hybrides ont été réalisés avec alimentation artificielle, dans deux étangs de 400 m2, avec une charge approximative de un sujet au m2, l'un pendant 2 ans, l'autre pendant un peu plus de 19 mois, avec exécution de vidanges intermédiaires pour contrôle de la croissance. Ils ont fourni les résultats suivants:

---

[1] Les T. nilotica élevés à Yaoundé sont originaires du Bassin du Tchad. Ceux de la Station de Bouaké sont originaires du Bassin de la Volta. Il existe peut-être des races régionales donnant des résultats différents lors des essais d'hybridation.

Elevage A (hybrides nés en septembre 1962)						
Date	Opération	Nombre total	Poids total (kg)	Poids individuel (g)		
				maximum	moyen	minimum
22.10.62	mise en charge	446	2,550		5,8	
26.12.62	vidange inter.	446	19,860	50	44,5	
28.2.63	"	415	25,750	70	62	50
3.4.63	"	415	36,250	110	87	70
5.6.63	"	414	44,950	150	108,5	80
22.10.63	"	404	74,000	250	183	140
3.2.64	"	397	107,600	330	271	220
29.4.64	"	391	128,900	380	329,5	245
11.10.64	vidange et pêche finale.	391	178,800	565	457,5	310
Elevage B (hybrides nés en janvier 1963)						
1.3.63	mise en charge	424	5,400		12,7	
4.4.63	vidange inter.	414	13,750	50	33,2	5
5.6.63	"	410	21,000	80	51,3	20
22.10.63	"	375	49,100	180	131	90
5.2.64	"	373	68,230	220	183	90
29.4.64	"	363	87,250	305	240,5	180
11.10.64	vidange et pêche finale	355	135,150	445	380,5	300

La croissance individuelle moyenne a été de 13,3 g par mois pendant la première année et de 22,5 g par mois pendant la deuxième année d'élevage. Ce dernier chiffre est très voisin de celui obtenu avec les hybrides de croisement mâle T. nilotica par femelle T. macrochir.

La production moyenne a été de 1.700 kg/ha/an pendant la première année d'élevage et de 2.560 kg/ha/an pendant la deuxième année.

La comparaison de ces résultats avec ceux obtenus dans des élevages de T. nilotica et T. macrochir effectués antérieurement à la Station de Bouaké dans des conditions assez voisines, ne permet pas de conclure à une supériorité des hybrides par rapport aux espèces parentales aux points de vue croissance individuelle et production. Une telle supériorité, si elle existe, ne doit pas être importante et ne nous semble pas, en tout cas, pouvoir atteindre celle signalée par Hickling (1959) pour les hybrides de T. mossambica obtenus par croisement de mâle africain avec femelle malaise.

4.4 Reproduction des hybrides F_1.

Les hybrides F_1 sont fertiles.

Deux essais de Back-cross ont été réalisés :

4.4.1 Croisement mâle hybride avec femelle T. macrochir

Un seul couple (mâle de 240 g, femelle de 75 g) a fait l'objet d'essai.

Placé pendant 9 mois dans un étang de 50 m2, il a donné 4 pontes et un total de 4.018 alevins. Deux élevages réalisés avec ces alevins ont montré que leur croissance n'est pas intéressante: 400 sujets placés dans un étang de 400 m2 et nourris artificiellement atteignent au maximum 100 g à un an. La proportion des mâles et des femelles est de 50 pour cent. La reproduction commence à 5 ou 6 mois.

4.4.2 Croisement mâle hybride avec femelle T. nilotica

Un seul couple (mâle de 240 g, femelle de 210 g) a fait l'objet d'essai.

Placé pendant un an dans un étang de 50 m2, il n'a donné que deux pontes à 9 mois d'intervalle et un total de 2.842 alevins. Un élevage de ces derniers a montré que leurs caractéristiques, semblables à celles des produits du back-cross précédent ne présentaient pas d'intérêt.

5 CROISEMENT MALE T. ZILLII LOCAL PAR FEMELLE T. ZILLII CONGO

Trois couples ont été placés fin 1962 dans 3 étangs de 50 m2. Les géniteurs du couple I pesaient 70 g (femelle) et 190 g (mâle); ceux des couples II et III entre 290 et 350 g. Seul le couple I s'est reproduit et à trois reprises entre février et septembre 1963. A partir de cette date, les trois couples se sont reproduits régulièrement tous les 2 à 3 mois, en donnant 2.000 à 3.000 alevins à chaque ponte.

Cinq élevages d'hybrides ont été contrôlés et n'ont présenté qu'un faible intérêt pour les raisons suivantes:

- proportion des sexes voisine de 50 pour cent

- croissance individuelle moyenne et production pas supérieures à celles des parents

- reproduction abondante à partir du 5ème mois.

6 CROISEMENT MALE T. ZILLII CONGO PAR FEMELLE T. ZILLII LOCAL

Trois couples ont été placés en février 1963 dans trois étangs de 50 m2. Les mâles pesaient 410,370 et 490 g et les femelles 50, 50 et 60 g.

Les couples I et IIIn'ont commencé à se reproduire qu'à partir d'octobre 1963 lorsque la femelle a atteint un poids de 200 g. Ils se sont reproduits ensuite régulièrement tous les 2 mois en 1964 en donnant de 3.000 à 10.000 alevins à chaque ponte. Quatre élevages de ces hybrides ont été contrôlés. Ils ont montré que ces hybrides ont les mêmes caractères que ceux du croisement inverse ci-dessus et présentent donc peu d'intérêt.

Le couple II laissé en place jusqu'en 1965 ne s'est reproduit qu'une seule fois en novembre 1963. Il a donné 314 hybrides dont l'élevage poursuivi jusqu'en mai 1965 a permis de constater:

- que cette population d'hybrides comportait une proportion sensiblement égale de mâles et de femelles;

- que les femelles avaient des organes génitaux atrophiés et étaient stériles;

- que la croissance individuelle moyenne des femelles était identique à celle des mâles, cette croissance étant nettement supérieure à celle des sujets des espèces parentes, du moins quand ceux-ci sont élevés les sexes étant mélangés.

Afin de tenter de déterminer si le résultat fourni par le couple II peut être répété et s'il est imputable au mâle ou à la femelle, les deux géniteurs ont été dissociés en janvier 1965 et accouplés chacun avec un géniteur provenant des couples I et III. Au 1/8/65, la femelle II ne s'était reproduite qu'une seule fois tandis que le mâle II a donné 3 reproductions successives.

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IV/E-6

THE ESTIMATION OF THE QUALITY OF CARP BY MEANS OF LENGTH/HEIGHT RATIO AND RELATIVE WEIGHT GAINS

by

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Abstract

The insufficiency of the length/height ratio as a measure for estimation of the quality of the carp is discussed. A new measure is introduced which is determined by the ratio of individual weight gain to the average gain of the same age individuals reared in similar conditions. Changes in the growth rate of carp in the first four years of life are analyzed on the basis of results obtained by tagging.

ESTIMATION DE LA QUALITE DE LA CARPE AU MOYEN DU RAPPORT LONGUEUR/HAUTEUR ET DE L'ACCROISSEMENT DE POIDS RELATIF

Résumé

L'auteur constate l'insuffisance du rapport longueur/hauteur en tant que mesure servant à exprimer la qualité de la carpe. Il propose une nouvelle mesure qui est déterminée par le rapport entre l'accroissement de poids individuel et l'accroissement de poids moyen d'individus du même âge élevés dans des conditions analogues. Les variations du taux de croissance de la carpe au cours de ses quatre premières années d'existence sont analysées à partir des résultats obtenus au moyen de marquage.

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LA ESTIMACION DE LA CALIDAD DE LA CARPA POR MEDIO DE LA RELACION TALLA/ALTURA Y DE LAS GANANCIAS RELATIVAS DE PESO

Extracto

Se examina la insuficiencia de la relación talla/altura como medida para la estimación de la calidad de la carpa. Se introduce una nueva medida que se determina por la relación entre la ganancia de peso de un determinado individuo y la ganancia media de los indivíduos de la misma edad criados en condiciones similares. Sobre la base de los resultados obtenidos mediante el marcado, se analizan los cambios en la tasa de crecimiento de la carpa en los cuatro primeros años de su vida.

1 LENGTH/HEIGHT RATIO AS A MEASURE OF SELECTION

In research on carp (Cyprinus carpio) selection it was found necessary to ascertain whether the length/height ratio, which has been commonly used for estimation of the breeding value of particular specimens (Demoll, Plehn and Walter, 1928; Tymowski, 1929; Cernajev, Nowak, 1932; Sklower, 1933) has a real value.

In order to answer the question, 1,500 specimens of two-year-old carp were measured. They were taken from two fish farms (Sarnów and Zeromin, Lódź District). The carp from the same pond and of the same age were derived from the same pair of spawners and it was only in the second year when they were reared in different ponds. The length/height ratio was determined from individual measurements. Then the correlation of weight and the length/height ratio was calculated (Table I).

Table I

The relationship between the weight and the length/height ratio

				Average		Correlation Coefficient
				length/height ratio	weight	
Farm	Year	Pond	n	$\bar{x} \pm \cdot t_{\bar{y}}$	$\bar{y} \pm \cdot t$	r_{xy}
Sarnów	1949	B	100	2.72 ± 0.037	320 ± 17.3	-0.089
	1949	A	110	2.56 ± 0.027	737 ± 26.1	-0.214^{x}
Zeromin	1948	B	358	2.72 ± 0.021	284 ± 5.9	-0.016
	1948	A	95	2.60 ± 0.031	494 ± 20.9	-0.204^{x}
	1948	C	255	2.51 ± 0.018	634 ± 11.0	-0.225^{xx}
Sarnów	1948	C	187	2.82 ± 0.035	619 ± 19.4	-0.336^{xx}
	1948	A	395	2.75 ± 0.025	636 ± 13.6	-0.401^{xx}

The coefficients of correlation between the weight of two-year carp and their length/height ratio were low and ranged between -0.089 and -0.401. The minus signs of the correlation coefficients reveal in all cases a tendency towards the improvement of shape together with increase of weight.

When analyzing the correlation coefficients for the carp of the same age group and farm, it can be seen that certain relationship exists between the average individual weight and the magnitude of the correlation coefficient. When growth is seriously inhibited (pond B) correlation coefficients are lower than at higher average individual weights (ponds A and B). Thus together with providing better trophic conditions, as measured by the average unit weight of the carp, the coefficients of correlation between the weight of various specimens and their length/height ratio give a measure of growth.

The increase of the average weight of the carp of the same origin is accompanied by the decrease of the average length/height ratio. Individual differences in the length/height ratio and the weight, accompanying changes in the trophic conditions and the mean deviations of these characteristics are set out in Table II.

Table II

The relationship between the mean deviations in the length/height ratio, mean deviations in weight and trophic conditions

Farm	Year	Pond	Average weight of fish g	Mean deviation length/height ratio	Mean deviation weight
Sarnów	1949	B	320	0.140	65.8
		A	737	0.110	106.0
Zeromin	1948	B	284	0.157	43.6
		A	494	0.115	77.6
		C	634	0.113	68.3
Sarnów	1948	C	619	0.186	103.0
		A	636	0.196	104.0

The increase of the average weight is accompanied by the decrease of mean deviation in the length/height ratio except in the ponds at Sarnów (1948). However, differences in the average weight as well as the average length/height ratio between the two ponds are very small.

On the other hand mean deviation in weight increases together with improvement of trophic conditions. The pond at Zeromin makes an exception in this respect. Decreasing differences in the length/height ratio in more favourable trophic conditions can be explained on the basis of the results of Tymowski's research (1929). He found out that in better feeding conditions growth in length is less than increase in height on account of the skeletal system. The length/height ratio is then changed.

The carp reared in unfavourable feeding conditions grow evenly in both directions and individual differences in conformation between the specimens are then quite pronounced. In favourable conditions a greater proportion of the specimens attains the length growth limit, and then growth in height begins to prevail. Consequently the whole population show better length/height ratio and individual differences of this ratio become smaller.

Greater uniformity of the body shape in better conditions goes to prove that the carp of higher length/height value improve their shape better than those showing lower ratios.

To sum up, the shape of the carp as measured by the length/height ratio cannot be used as a basis for carp evaluation as this is a variable characteristic, depending on trophic conditions, and poorly correlated with the weight.

2 GROWTH GAINS AS A MEASURE OF THE QUALITY OF CARP

It seems worth considering which characteristics should be accepted as the basis for estimation of the individual quality of carp. Weight could make a convenient measure of fish quality, as it can always be directly recorded, but for an objective evaluation measure it is necessary to use increase in body weight.

Grouping the carp in this respect into two classes:

D - those growing above the average

M - those growing below the average

it is possible to differentiate within them all the possible combinations of the growth ratesin the course of the first four years:

	Age group				Age group			
	K_1	K_2	K_3	K_4	K_1	K_2	K_3	K_4
Combination:	D	D	D	D	M	M	M	M
	D	D	D	M	M	M	M	D
	D	D	M	D	M	M	D	M
	D	M	D	D	M	D	M	M
	D	M	M	D	M	D	D	D
	D	M	D	M	M	D	M	D
	D	D	M	M	M	M	D	D
	D	M	M	M	M	D	D	D

The rate of growth may undergo some changes in various periods of life. In the two-year growing system good growth in the second year is the most essential; in three-year growing it is the third year when growth is most important for the yield of marketable carp. This means that individual estimation of carp quality should be based on growth gains in various years. Such an estimation can be made on individually marked carp at the same time as records are kept on the life history of each specimen.

However, the growth gain itself does not make a sufficient measure as it is also affected by the feeding conditions and will be related to trophic conditions in the pond. It is the purpose of selection to choose specimens that grow better than the others of the same age. The growth gain ratio was found to make such a measure (Stegman, 1965). This is a quotient of individual year growth gain of a given specimen to the average individual growth gain of fish of the same age and reared in the same conditions. Thus the average growth gain of specimens of the same age makes an index characterizing feeding conditions in the pond. The same age full-scale carp reared together with the selected specimens (mirror carp) are now used as standards after one month of life.

The growth gain ratio of the specimens with average growth rate is 1.0; it is above 1.0 in those with above average growth rate, and below 1.0 in those with under the average growth rate. On account of the different growth rates in various years the growth gain ratio is calculated for every year of life separately.

As an example growth gains and calculated growth gain ratios for a number of carp are tabulated below.

Table III

Growth gains of five carp and their calculated growth gain ratios

Np.	Growth gains g			Growth gain ratios		
	K_2	K_3	K_4	K_2	K_3	K_4
2561	712	1700	700	1.03	1.00	0.61
2563	710	1750	650	1.03	1.03	0.57
2569	690	1670	950	1.00	0.98	0.83
2575	530	1780	1100	0.77	1.05	0.96
2578	550	1960	800	0.80	1.15	0.70

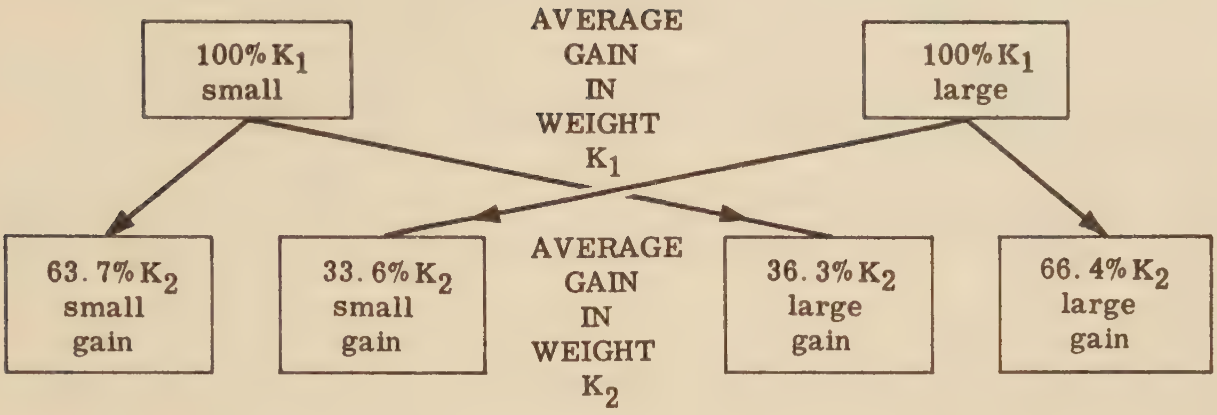
100% K_1 small
AVERAGE GAIN IN WEIGHT K_1
100% K_1 large
63.7% K_2 small gain
33.6% K_2 small gain
AVERAGE GAIN IN WEIGHT K_2
36.3% K_2 large gain
66.4% K_2 large gain

Fig. 1 The changes in the growth rate in percent of the number of specimens

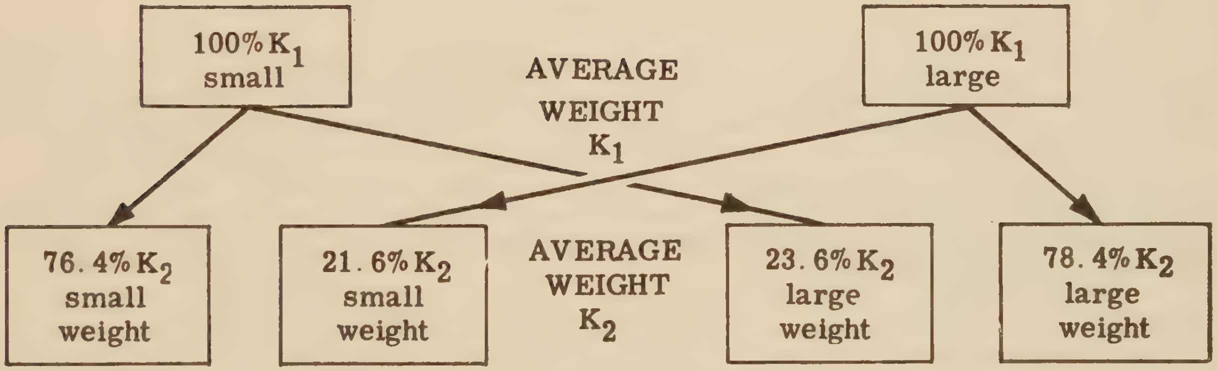
100% K_1 small
AVERAGE WEIGHT K_1
100% K_1 large
76.4% K_2 small weight
21.6% K_2 small weight
AVERAGE WEIGHT K_2
23.6% K_2 large weight
78.4% K_2 large weight

Fig. 2 The changes in the individual weight given in the percent of the number of specimens

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It is the purpose of the breeder to select spawners that showed above average growth gain ratio in all the four years of their life. The higher the value of the ratio the better will be the quality of the carp. On the other hand, the growth in the fourth year is not essential as it does not affect production of the commercial carp.

Length measurement, which is closely correlated with weight, may be of help in the estimation of height. The author's findings in this respect agree with those of the other authors (Tymowski, 1929; Cernajev and Nowak, 1932; Sklower, 1933).

It was also interesting to study quantitative relations in large carp and small carp classes in the first and second year of life. Data on growth collected from individually tagged carp are given in Fig.1. Within the weight groups, changes also occur as indicated in Fig.2.

It can be seen while comparing Figs. 1 and 2 that the number of specimens in the second year of life is not the same in the corresponding classes in respect to weight and gain.

The differences in the "Large" class reared from the "Large" fry are as follows:

$$78.4\% - 66.4\% = 12.0\%$$

whereas in the "Small" class reared from "Small" fry they are:

$$76.4\% - 66.4\% = 12.7\%$$

Thus 12 percent of the two-year-old carp are those that belong to the over-the-average weight group, though in the second year they gained below the average, which means that their growth gain in the first year was very high and compensated the lower gain of the second year.

Similarly, 12.7 percent of the two-year-old carp are those that belong to the "Small" weight group, though in the second year they gained above the average. The greater proportion of the "Large" fry, i.e. about two-thirds, remains simultaneously in the "Large" weight and gain class in the second year. A part of the "Large" fry, i.e. about one-eighth, remains in the "Large" weight but "Small" gain class in the second year. Only one-fifth of the "Large" fry show both gain and weight below the average in the second year of life. Similar, though more complex are group shiftings in the second and third year of life. These relationships are presented in Fig.3.

The majority of specimens remain in the same weight group in the following year. However, in this group are also specimens that belong to the opposite class in respect to growth gain. In order to secure a desired quantity of carp that would show weight and gain over the average in the second as well as the third year of life, at least 1.8 times more two-year-old carp with above the average weight should be taken, than the demand.

It seems worth considering what the average gain of the above average selected specimens is in one year and in the following year. The "Large" fry show average gains between 2 percent and 17.9 percent higher than the average for the whole population in the following year of life. "Small" fry show gains of 2.4 percent to 13.0 percent lower. When analyzing the changes in the second and third year of life it can be concluded that two-year-old carp of "Large" weight showed, as K_3, up to 9.5 percent higher average weights, whereas the "Small" two-year specimens showed 11.2 percent lower weights as K_3. In gain classes these values were slightly lower, i.e. 7.2 and 6.3 percent respectively.

It can be concluded that the ratio of the annual gains of the given specimens to the average group gain in weight makes a satisfactory measure of the estimation of growth trend of the carp. When selecting large specimens from the fry (K_1) there is enough proof to believe that two-thirds of them will manifest desirable growth rates in the second year, and 39 percent will show a fast growth rate also in the third year.

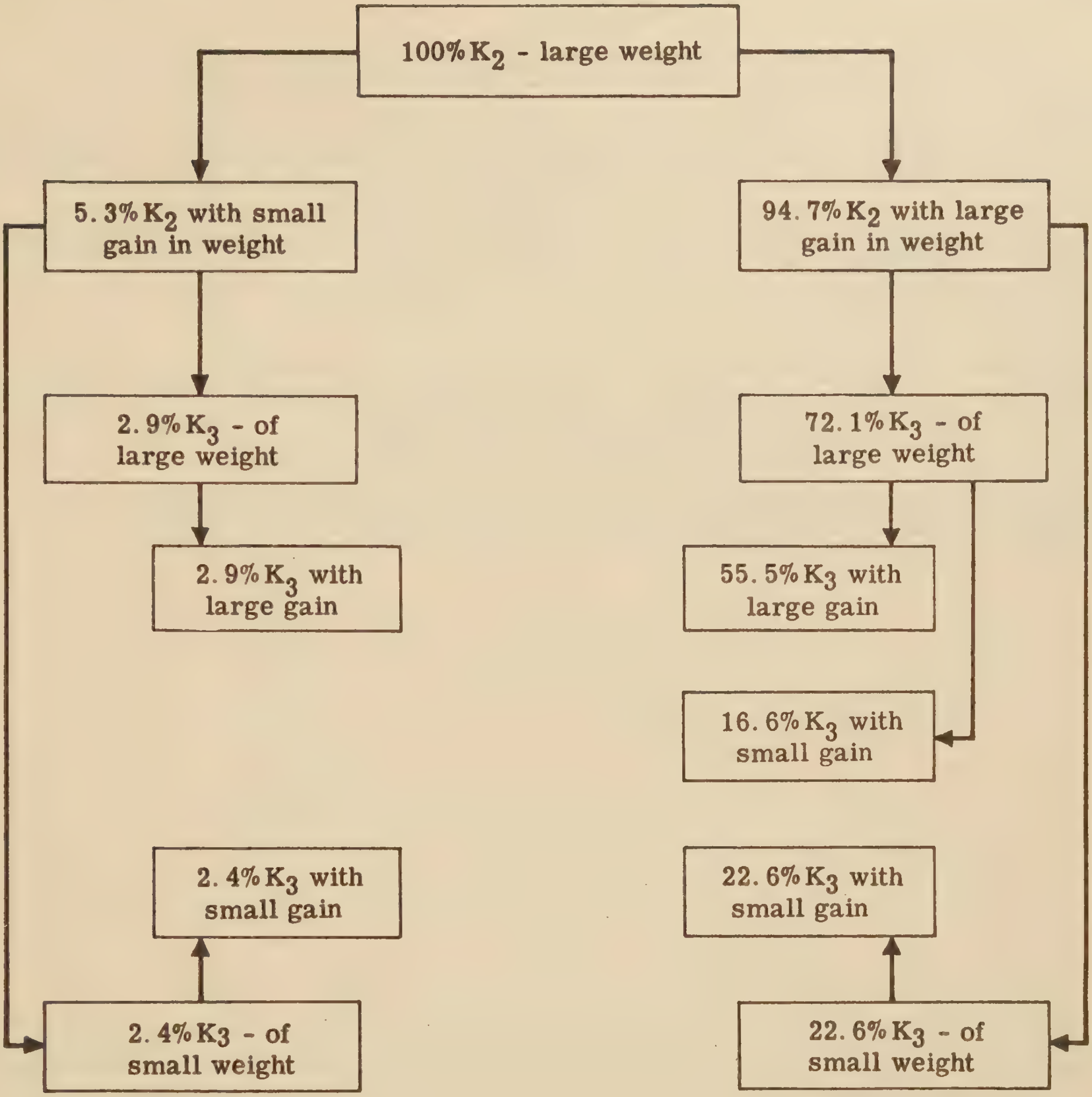
100% K_2 - large weight
5.3% K_2 with small gain in weight
94.7% K_2 with large gain in weight
2.9% K_3 - of large weight
72.1% K_3 - of large weight
2.9% K_3 with large gain
55.5% K_3 with large gain
16.6% K_3 with small gain
2.4% K_3 with small gain
22.6% K_3 with small gain
2.4% K_3 - of small weight
22.6% K_3 - of small weight

Fig. 3 The changes in the growth rate of carp during the third year of life

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THE GROWTH OF FEMALES AND MALES OF CARP (CYPRINUS CARPIO)

by

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Abstract

Based on the results of growth analysis in ten Polish carp populations, from the first to the fourth year of life (K_1 to K_4), it has been found that growth differentiation between females and males within one genetically homogeneous population occurs at K_4, mostly to the advantage of females. There may be populations where growth differentiation between the sexes occurs at K_3 or even at K_2. In such cases the males are found to grow better.

The most sensitive measures for revealing growth differences between females and males are found to be weight gain ($\triangle_g$), body length (l.c.), weight of the body (C) and body length gain ($\triangle_{l.c.}$). The height of the body (alt. corp.) proved to be the least reliable measure for this purpose.

It has been shown that growth differentiation between the sexes earlier than at K_4 is not the result of a high growth rate of the population, but probably connected with earlier maturation.

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CROISSANCE DES CARPES FEMELLES ET MALES (*CYPRINUS CARPIO*)

Résumé

Partant des résultats de l'analyse de croissance de dix populations de carpes polonaises, de la première à la quatrième annee (K_1 à K_4), il a été constaté qu'à l'intérieur d'une population génétiquement homogène, la croissance des femelles et des males se différencie en K_4, généralement à l'avantage des femelles. Il peut y avoir des populations où cette croissance différentielle se manifeste en K_3 ou même en K_2. Dans de tels cas, on constate que ce sont les males dont le taux de croissance est le plus rapide.

Pour déceler les différences de croissance entre femelles et males, on a constaté que les mesures les plus précises étaient les suivantes: gain en poids (Δ C), longueur (l.c.), poids (C) et accroissement de longueur (Δ l.c). La hauteur du corps (alt. corp.) s'est avérée être la mesure la moins précise à cette fin.

Il a été prouvé que lorsqu'une croissance différentielle se produit avant K_4 elle n'est pas due à un taux de croissance élevé de la population, mais est probablement liée à une maturation plus précoce.

EL CRECIMIENTO DE HEMBRAS Y MACHOS DE CARPA (*CYPRINUS CARPIO*)

Extracto

Sobre la base de los resultados de los análisis de crecimiento de diez poblaciones de carpas polacas desde el primero al cuarto año de edad (K_1 a K_4), se ha observado que la diferenciación del desarrollo entre las hembras y los machos dentro de una población genéticamente homogénea se verifica en K_4, casi siempre a favor de las hembras. Pueden existir poblaciones en las que la diferenciación del desarrollo entre los sexos se verifica en K_3 o incluso en K_2. En tales casos, se observa que los machos crecen más.

Las medidas más apropiadas para revelar las diferencias de crecimiento entre hembras y machos se ha visto que son: la ganancia de peso (Δ_C), la talla corporal (l.c.), el peso corporal (C) y la ganancia de talla ($\Delta_{l.c.}$). La altura del cuerpo (alt.corp.) resultó ser la medida menos segura para tal fin.

Se ha comprobado que la diferenciación del crecimiento entre los sexos en fases anteriores a K_4 no es el resultado de un elevado ritmo de crecimiento de la población sino que, probablemente, está relacionado con una maduración más temprana.

1 INTRODUCTION

Wunder (1934) was the first to observe differences in carp (Cyprinus carpio) growth in the two sexes. He found that in three and four years old carp, showing markedly inhibited growth, females were heavier than males by about 30 to 50 percent. The weight differences were so striking that it was suggested that they might have occurred only in degenerated specimens (Walter, 1934). Wunder (1936; 1942) did not find such high differences in his later investigations.

Eichler (1940) noted a tendency for fast increase in weight in carp females in their third year of life (K_3): no differentiation occurred in measurements of head length, greatest body depth, body depth at anus, and greatest body width, in third year of life. Wlodek (1959) analysed growth of carp of a genetically homogenous population from the second to the fifth year of life (K_2 to K_5). He found slight differences in the average weight in K_3, females being heavier, and statistically significant differences at K_4 and K_5, the females then being 15 percent heavier than the males. However, Wlodek observed that if the population matures earlier, K_3 females may already be significantly heavier.

According to Krauper (1964) the weights of two and three year old carp are not affected by the sex. The females show greater weight increase only at K_4 and the following years. In his opinion, intensive growth may affect earlier maturity, particularly of males. But even a very intensive development of the gonads does not inhibit the linear growth of the carp body at K_2 and K_3.

At the period of maturation the weight differences between males and females may be partly the result of different degrees of gonad development in males and females of the same age. It has been found that differentiation of male and female gonads occurs between the second and the third year of life (Wunder, 1936; Lühmann and Mann, 1957; Wlodek, 1959; Solewski, 1958), whereas the weight of the other organs is similar in both sexes at K_3 and K_4.

Alm (1959) studied the effect of growth rate on the advancement or retardation of the age of maturity of certain fishes. He found that the faster the growth rate of the fish the earlier their sexual maturity. Fish growing either very fast, or very slowly, from the beginning of their life, attain maturity at a smaller size than do those of moderate growth rate. According to Alm's opinion, check in growth rate which is observed in fish at the period of maturation is primarily the result of insufficient food and not of any inhibitory effect of sex hormones. Other authors (Bieniarz, 1963; Hermann, 1940; Went, 1961) are also of the same opinion.

Observations described in the present paper show that carp females reared in ponds begin to grow in weight better than males in the fourth year of life. However, when a population matures in the third year of life, females may already be slightly heavier in the third year (K_3).

2 PROBLEM

The work aimed at:

(i) establishing at what age do real differentiations of growth rate occur between female and male carp reared in central, south-west, and south-east regions of Poland;

(ii) finding out whether for the carp of these regions the age of differentiation is regular, irrespective of the origin of the fish and environmental conditions;

Table I

Origin and number of carps examined

Region of Poland	No. of population	Year of spawning	Number of females	Number of males	Number of total
South - West	I	1950	18	10	22
-"- -"-	II	1951	15	11	36
-"- -"-	III	1950	24	17	41
-"- -"-	IV	1951	44	50	94
-"- -"-	V	1956	43	34	77
Central	VI	1951	48	45	93
-"-	VII	1955	32	38	70
South - East	VIII	1951	33	32	65
South - West	IX	1956	29	24	53
Central	X	1959	43	48	91
	Grand Total		329	309	638

(iii) examining whether growth differentiation concerns only weight or affects other growth indices as well.

3 MATERIAL

Carp specimens which retained tags from the first to the fourth year of life were used for growth analysis; 638 specimens were taken for analysis, 329 females and 309 males. They were collected from general populations as follows: 50 fish of body length higher than average for the population and 150 fish taken at random. The material consisted of 10 test populations representing three regions of Poland (Table I).

Each test population was derived from the offspring of one pair of spawners, and was thus genetically homogeneous material. Environmental differences within one population were eliminated by rearing all the specimens in one pond until the age K_4. The first measurements of K_1 together with tagging, were made in the spring. The later measurements were made every year at the time of autumn fishing.

4 METHODS

Five measurements were used for estimation of the growth rate of carp females and males in the first, second, third and fourth year of life (K_1, K_2, K_3 and K_4) (Table II):

body weight in g (c)
annual increase of body weight ($\triangle$ c)
body length (l.c)
annual increase in body length ($\triangle$ l.c)
the greatest body depth (alt. corp.)

The differences between average values of the measurements for females and males were estimated by the analysis of variance.

5 RESULTS

The differences between the average measurements for females and males are presented in Table II. These show that:

(i) In the first year (K_1) the differences between the sexes, in all the populations, were very small and statistically insignificant. On this basis it was possible to assume that every test population at the onset of the examinations made a homogeneous group in relation to growth.

(ii) In the second year (K_2) somewhat greater differences occurred, but it was only in the populations VIII and X that significant growth differences between populations were found; in the population VIII the females were larger, in X the males.

(iii) In the third year (K_3) significant differences were found in the population III to the advantage of the males. In the populations VIII and X the significant advantage of the same sex remained from the previous year only in body length. In the population V the males showed greater body length growth ($\triangle$ l.c) than the females.

(iv) In the fourth year (K_4) significant greater weight growth ($\triangle$ c) was noted in females in all the populations, except X. In the last population both sexes showed practically the same average weight at K_4. In the other measures differences occurred in all possible combinations.

Table II

Difference between average values of the growth measures of female and male carp

No. of population	K1			K2				
	$\bar{c}_{♀} - \bar{c}_{♂} = \bar{\Delta}_{c♀} - \bar{\Delta}_{c♂}$	$\overline{l.c}_{♀} - \overline{l.c}_{♂} = \bar{\Delta}_{l.c♀} - \bar{\Delta}_{l.c♂}$	$\overline{alt}.♀ - \overline{alt}.♂$	$\bar{c}_{♀} - \bar{c}_{♂}$	$\bar{\Delta}_{c♀} - \bar{\Delta}_{c♂}$	$l.\bar{c}.♀ - l.\bar{c}.♂$	$\bar{\Delta}_{l.c♀} - \bar{\Delta}_{l.c♂}$	$\overline{alt}.♀ - \overline{alt}.♂$
I	- 3	- 0.3	0	- 21	- 22	- 0.3	0	+ 0.2
II	- 8	+ 0.3	+ 0.1	- 23	- 31	- 0.3	- 0.6	0
III	- 2	- 0.1	0	- 44	- 41	- 0.6	- 0.7	- 0.1
IV	- 7	- 0.1	- 0.1	+ 37	+ 43	- 0.3	+ 0.4	+ 0.1
V	0	- 0.3	0	+ 15	+ 16	0	+ 0.3	+ 0.1
VI	- 1	- 0.2	0	+ 19	+ 20	0	+ 0.2	+ 0.1
VII	+ 16	+ 0.5	+ 0.3	+ 46	+ 30	- 0.5	0	+ 0.2
VIII	- 4	0	+ 0.1	+ 55*	+ 51**	+ 0.7*	+ 0.7*	+ 0.3*
IX	- 4	- 0.2	- 0.1	+ 10	+ 14	+ 0.7	+ 0.9*	0
X	- 7	- 0.3	- 0.1	- 58**	- 51**	- 0.8**	- 0.5	- 0.3*

No. of population	K3					K4				
	$\bar{c}_{♀} - \bar{c}_{♂}$	$\bar{\Delta}_{c♀} - \bar{\Delta}_{c♂}$	$l.\bar{c}.♀ - l.\bar{c}.♂$	$\bar{\Delta}_{l.c♀} - \bar{\Delta}_{l.c♂}$	$\overline{alt}.♀ - \overline{alt}.♂$	$\bar{c}_{♀} - \bar{c}_{♂}$	$\bar{\Delta}_{c♀} - \bar{\Delta}_{c♂}$	$\overline{l.c}_{♀} - \overline{l.c}_{♂}$	$\bar{\Delta}_{l.c♀} - \bar{\Delta}_{l.c♂}$	$\overline{alt}.♀ - \overline{alt}.♂$
I	+ 102	+ 122	- 0.9	+ 1.1	+ 0.6	+ 443*	+ 341**	+ 2.4*	+ 1.6**	+ 1.1*
II	+ 128	+ 151	+ 0.9	+ 1.3	+ 0.2	+ 416*	+ 288**	+ 2.2*	+ 1.3*	+ 1.1*
III	+ 233*	+ 276**	+ 1.2	+ 1.9**	+ 0.9**	+ 510**	+ 278**	+ 2.1**	+ 1.0**	+ 1.1**
IV	+ 16	- 21	+ 0.4	0	+ 0.2	+ 175	+ 159**	+ 0.6	+ 0.1	+ 0.1
V	- 30	- 46	- 0.7	- 0.8**	+ 0.1	+ 225*	+ 256**	- 0.8	0	+ 0.4
VI	+ 41	- 23	+ 0.1	+ 0.1	+ 0.1	+ 396**	+ 355**	+ 1.7**	+ 1.6	+ 0.1
VII	+ 58	- 12	- 0.7	+ 0.3	+ 0.2	+ 316**	+ 256**	+ 2.2.**	+ 1.5**	+ 0.4*
VIII	+ 26	- 29	+ 0.6**	- 0.1	+ 0.1	+ 298**	+ 272**	+ 1.3**	+ 0.7	+ 0.7**
IX	- 43	- 53	0	- 0.6	+ 0.2	+ 210**	+ 253**	+ 1.0*	+ 0.9**	+ 0.1
X	- 84	- 26	- 0.9**	- 0.1	0	- 6	+ 78*	- 0.7*	+ 0.1	- 0.2

N.B. For symbols see text

* significant at 0.01 probability level

** significant at 0.05 probability level

Table III

The sets of occurrence of the significant differences
between measurements for female and male carp

c	$\triangle_{c}$	l.c	$\triangle_{l.c}$	alt.c.	No. of sign. diff.
xx	xx	xx	xx	xx	
xx	xx	xx	xx	x	
x	xx	x	xx	x	
x	xx	x	x	x	
x	xx	x	x	x	25
xx	xx	xx	xx	-	
xx	xx	xx	-	xx	
xx	xx	xx	-	x	
x	xx	-	xx	xx	
xx	xx	x	xx	-	20
x	xx	-	-	-	
-	x	x	-	-	4
-	xx	-	-	-	
-	-	-	xx	-	
-	-	xx	-	-	
-	-	-	x	-	
-	-	xx	-	-	5
11	13	12	10	8	54

N.B. For symbols see text

A graphic representation of all the combinations of sets of significant differences found between the average values of the measurements for females and males is given in Table III. Out of 180 calculated differences, 54 were statistically significant, 25 occurred in all the five measures, 20 simultaneously in four measures and four sets, and 9 significant differences occurred in two sets, and in one measure in seven sets. The summing up (the last row in Table III) shows that the most sensitive measure for revealing growth differences between female and male carp is growth rate of body weight (Δ_{C}), then, successively, growth in length (l.o.), body weight (C), annual increase in length ($\Delta_{l.o}$) and body depth. Only body depth was not found to be of great use in this respect as it rarely helps to reveal the differences, and if it does, it is in cases where the other measures also detect significant differences.

6 DISCUSSION

On the basis of the growth analysis of females and males of the carp in the first four years of life it can be concluded that:

(i) growth differentiation in the Polish carp, affected by the sex difference, occurs markedly only in the fourth year of life (K_4), mostly to the advantage of the females;

(ii) there may be populations where a significant advantage of one sex over another can be seen already at K_3 and even at K_2. At that age males may also happen to be the better growing sex. From the breeding point of view this finding may be of great importance. Getting the males relatively or even better growing than the females in the first three years would make a goal for further selection, if this characteristic were found to be hereditary;

(iii) growth differences between females and males of the carp are revealed most frequently in weight gains (Δ_{C}) and in the other measurements, though not always at the same time as Δ_{C};

(iv) in connection with Alm's results (1959) on the effect of growth rate on maturation of fish, a separate case of significant growth advantage of females over the males at K_3 in the population III was analysed. It was the population which derived from the same fish farm as the population IV and V. The carp from that farm grew very fast, as can be seen in Fig.1; at the age K_1 the carp attained from 80 to 280 g, in the second year the gain of weight was from 710 to 830 g, in the third 730 to 1,625 g and in the fourth year 1,060 to 1,660 g. The population III grew similarly to population IV, and worse than population V. Thus an earlier differentiation of growth which occurred in the population III in the third year of life (K_3) was not a consequence of higher growth rate. It might be the result of an inherited characteristic of earlier maturation, as discussed by Alm (1959), Wlodek (1959), and Krauper (1964).

The fact that in this climate the carp males may mature in the second, and females in the third year of life has often been noted, for example "Aischgrund carp" (Hofmann, 1935). An earlier maturation of males than in K_3, and females than in K_4 does not make a desirable characteristic for breeding practice in our climatic zone. Assuming that there are populations which attain sexual maturity earlier irrespective of growth rate, and keeping in mind that such populations are not desirable in fish ponds, it seems reasonable that they should be substituted by others which mature at a later age.

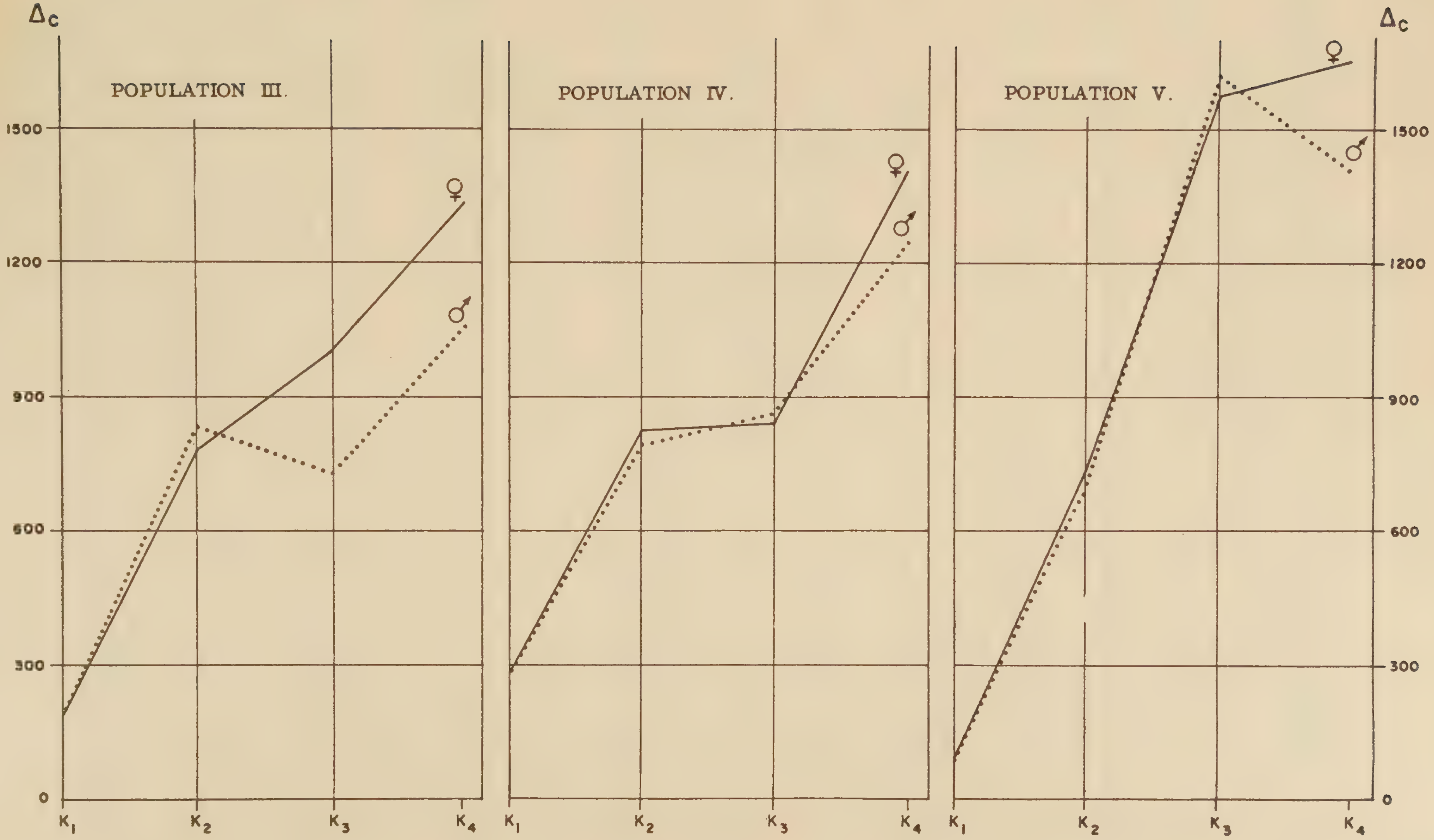

Fig.1 Annual growth rates of females and males of three carp populations. The growth rate does not affect the age at which differentiation in size between sexes occurs.

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EFFICIENCY OF MASS SELECTION AND SELECTION FOR RELATIVES IN FISH CULTURE

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Abstract

The report deals with methods of performing mass selection and testing for relatives in fish culture. The efficiency of mass selection depends on selection intensity and heritability. Intensity of mass selection due to high fertility of fish is two to three times higher than that of selection for relatives. The latter is impeded by the impossibility of growing many families simultaneously. Heritability of most important characters, such as the body weight, is not great, but it can be increased by means of crossing or establishing identical environmental conditions.

A comparison between the efficiency of mass selection and selection for relatives shows the latter to be more profitable only in case the heritability of selective characters is very low (not more than 0.1 - 0.15). The best way out of the situation is to resort to combined selection i.e. perform successively mass selection and testing for relatives in one and the same generation.

IV/E-8

EFFICACITE DE LA SELECTION MASSALE ET DE LA SELECTION GENEALOGIQUE EN PISCICULTURE

Résumé

Le rapport traite des méthodes selon lesquelles se pratiquent la sélection massale et la sélection généalogique en pisciculture. L'éfficacité de la sélection massale dépend de l'intensité de la sélection et des caractères héréditaires. En raison de la forte fécondité des poissons, l'intensité de la sélection massale est deux ou trois fois plus élevée que celle de la sélection généalogique. Cette dernière est rendue difficile par le fait qu'il est impossible d'élever simultanément de nombreuses familles. La transmissibilité des caractères les plus importants, tels que le poids, n'est pas très élevée mais peut être améliorée au moyen de croisements ou en créant des conditions de milieu identiques.

La comparaison entre l'efficacité de la sélection massale et celle de la sélection généalogique prouve que cette dernière donne de meilleurs résultats uniquement dans le cas où la transmissibilité des caractères choisis est très faible (pas plus de 0,1 - 0,15). La meilleure solution consiste à combiner les deux méthodes, c'est-à-dire à pratiquer successivement la sélection massale et la sélection généalogique avec des individus appartenant à la même génération.

EFICACIA DE LA SELECCION MASAL Y DE LA SELECCION POR PARENTESCO EN LA PISCICULTURA

Extracto

Se ocupa este informe de los métodos de realizar la selección en masa y del ensayo de parentesco en la piscicultura. La eficacia de la selección en masa depende de la intensidad de la selección y de la heredabilidad. La intensidad de la selección en masa, debido a la elevada fertilidad de los peces, es dos a tres veces más alta que la de la selección de parentesco. Esta última se ve impedida por la imposibilidad de criar muchas familias simultáneamente. La heredabilidad de los carácteres más importantes tales como el peso corporal no es grande pero puede aumentarse por medio de cruzamientos o estableciendo condiciones ambientales idénticas.

La comparación entre la eficacia de la selección y la selección de parentesco muestra que esta última es más beneficiosa solamente en caso de que la heredabilidad de los carácteres selectivos sea muy baja (no más de 0,1 - 0,15). La mejor forma de resolver la situación es recurrir a la selección combinada, es decir, realizar sucesivamente la selección en masa y el ensayo de parentesco en una misma generación.

1 INTRODUCTION

The importance of selection is increasing considerably with the development of pond fish breeding and domestication of new species of fresh-water fish. Selection efficiency depends to a great extent on a good choice and skilful application of modern methods of selection. Of paramount importance is a reasonable use of mass selection and selection for relatives, as well as the best possible combination of inbreeding and outbreeding which accompany them.

The present paper is an analytical survey of genetic methods of selection adapted for work with pond fish. These methods were tested in the process of creating a new breeding stock of carp (Cyprinus carpio), fitted to the living conditions in the northern and eastern part of the U.S.S.R. (Kirpitschnikov, 1959; 1961; 1966a; 1966b). The choice of initial breeding material was conditioned by the severity of climate in those regions. We have crossed the European cultured carp of Galician origin with carp ("sazan") from Amur River (C. carpio haematopterus Temm. and Schl.) notable for its great winter-hardiness and high rate of growth (Kirpitschnikov, 1943; 1949). In the course of our work, first to fifth hybrid generations were successively obtained (Fig. 1). In each generation, beginning from the second, we performed mass selection of the best individuals for growth rate and appearance (Table I), and tested spawners for relatives (mainly for offspring). Careful consideration was given to choosing an appropriate system of crossings, especially for elaboration of methods for commercial crossing in carp breeding.

Table I

Average severity and intensity of selection for weight in second to fourth generations of the Ropsha hybrid carp

Generation	Number of crossings	Age	Severity of selection V%	Intensity of selection i
2	2	0+, 1+	5.1	2.2
3	7	0+, 1+ rarely	0.3	2.8
4	8	mainly 0+	1.6	2.7
	6	mainly 1+	5.2	2.2

Experience gained by selecting the northern hybrid ("Ropsha") carp has allowed unbiased estimation to be made of the expediency and efficiency of the most important methods for selection used in fish culture.

2 MASS SELECTION

The efficiency of mass selection is easily expressed by a simple equation (Falconer, 1960):

$$R = i \sigma h^2 = S h^2 \qquad (1)$$

where

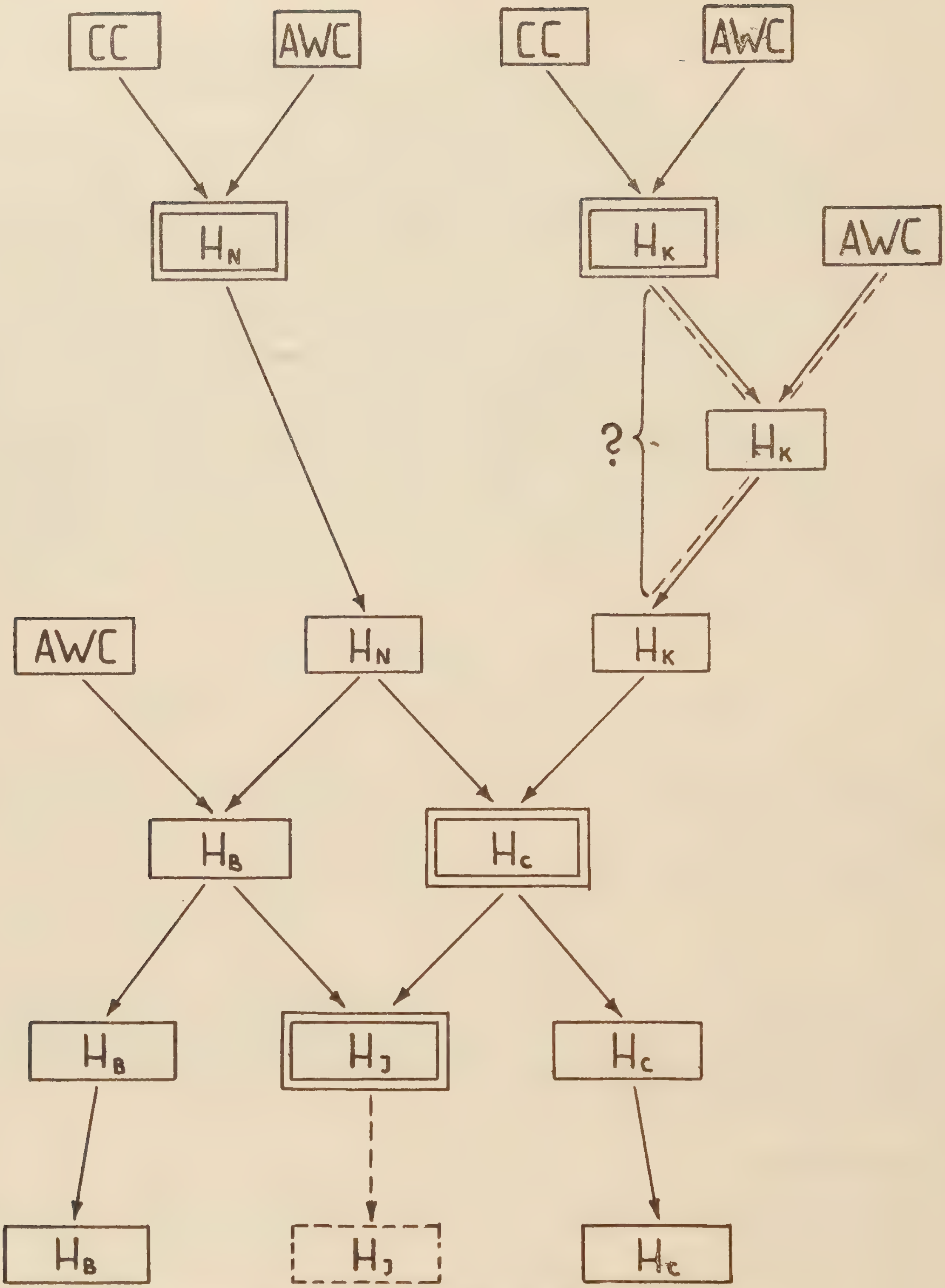
R = hereditary improvement of character for one generation;

S = selective differential (difference between mean for selected individuals and initial population mean);

i = intensity of selection i.e. selective differential expressed in mean square deviations;

h^2 = heritability of character;

σ = variability of initial population.


CC
AWC
CC
AWC
H_N
H_K
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?
H_K
AWC
H_N
H_K
H_B
H_C
H_B
H_J
H_C
H_B
H_J
H_C

Fig. 1 Scheme of creating breeding stock of the Ropsha hybrid carp.

CC – cultured mirror carp, AWC – Amur wild carp,

H_N and H_K – hybrids of Novgorod and Kursk strains,

H_B, H_C and H_I – hybrids of backcross, criss-cross (inter-linear) and intermediate strains.

Double frame outlines heterosis combinations.

'?' denotes uncontrolled crossing during the war in 1941-44

Let us consider successively the possibilities of increasing each of the terms in the right part of the equation when performing selection of fish.

2.1 The intensity of selection

The intensity of selection may be quite substantial in those species of fish which are characterized by high fertility. In such cases we are able to leave for breeding only a small part of a grown population; the vast majority of individuals are to be rejected. The number of best specimens left for breeding in percentage is called the selection severity coefficient.

$$v = \frac{n \times 100}{N} \% \qquad (2)$$

where N = initial number of individuals,
and n = number of selected individuals.

Selection severity coefficient in fish of such great fertility as carp can be easily brought to one percent or even 0.1 percent. Occasionally we used in selecting first-year carp still more rigid norms of rejection, keeping for breeding purpose only 0.05-0.02 percent of the population (1:2,000 to 1:5,000).

Such an increase in selection severity requires, however, a rise in population up to many tens or even hundreds of thousands of individuals. As illustrated in Fig. 2, the increase in the value of i falls off, while the number of individuals increases. With $N > 1{,}000$ the further accretion of i is so negligible that trouble and money spent on growing fish will not be justified by the result. In practice the ratio 1:500 - 1:1,000 ($v = 0.1$ to 0.2 percent) should be regarded as maximum severity of selection. To choose with such severity 100 fish, about 50 to 100 thousand individuals must be bred. This is quite possible in carp farming if one is growing fingerlings. Reduction in selection severity to one percent (1:100) or even to two percent (1:50) results in a comparatively small decrease of selection intensity. If the fertility of the fish was low, selection with ratio 1:20 ($v = 5$ percent) would be permissible. A further reduction in severity is undesirable as it would be followed by a sudden drop of the value i (Fig. 2).

It should be taken into account that increased size of initial population, and therefore enhanced i may be accompanied (as much as fish bred in ponds are concerned) by reduction in heritability (h^2). It has been stated by many investigators (Nakamura and Kasahara, 1955; 1956; 1957; Moav and Wohlfarth, 1963; Krjageva, 1965) that in young of carp grown under conditions of high density, the weight distribution curve becomes markedly asymmetric; a few 'jumpers' (champions) appear, whose rate of growth considerably surpasses that of their companions of the same age. The removal of these jumpers calls for the appearance of new ones. Food competition is responsible for this; the largest individuals are always masters of the situation. Heritability of differences between champions and other members of the population must be markedly reduced. The more strictly we select in a population, the more likely shall we choose just these champions, and the lower will be, consequently, the rate of heritability.

In the presence of food competition, an increase in severity and intensity of selection above a certain limit may have a bad effect.

2.2 Variability of initial population

The variability of initial population (σ) should be sufficiently great; if σ is near zero, even with a very high intensity of selection and considerable heritability (about 0.6 - 0.8), the efficiency of selection may turn out to be low. Let us suppose that $i = 3$, $h^2 = 0.6$ and $\sigma = 0.1$ g; then according to formula (1), $R = 0.18$ g. This means that in order to increase the weight of fish only by 1 g, more than five generations of selective breeding are needed. This would be increased only at the expenditure of an increase in genetic heterogeneity of population. An increase in non-hereditary variability caused by

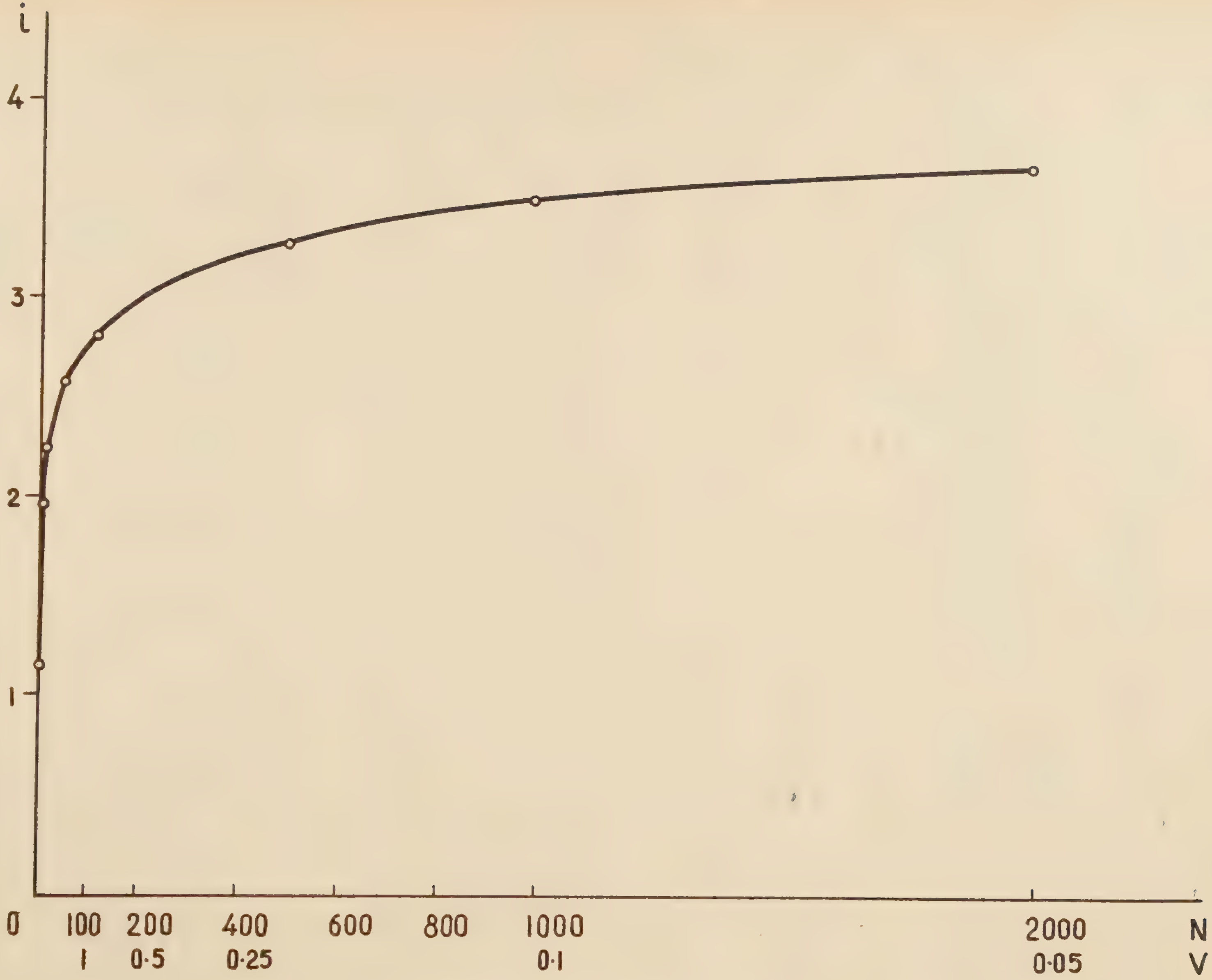


Fig. 2 Relation between selection severity and selection intensity.

N - size of population required for selecting on individual,

v - selection severity (%)

i - selection intensity.

environmental influences will produce reduction in heritability and will not enhance the efficiency of selection.

2.3 Heritability

Heritability (h^2) may be enhanced in several ways:

(i) A simple, much practised method is that of crossing unrelated individuals, including crossing between lines, breeding stocks, varieties, subspecies, and occasionally, even species;

(ii) A more difficult, but capable of producing good results, is the method of unifying fish growing conditions previous to selection. As is well known, heritability in the broad sense is the relation between the whole genetic variance and total variance (Lush, 1949; Lerner, 1958; Falconer, 1960):

$$h_1^2 = \frac{\sigma_G^2}{\sigma_{Ph}^2} \qquad (3)$$

Total variance, in its turn, expands into a number of components

$$\sigma_{Ph}^2 = \sigma_G^2 + \sigma_\varepsilon^2 + \sigma_j^2 \qquad (4)$$

where σ_ε^2 is environmental variance, and σ_j^2 is variance of interaction between environment and genotype. The selectionist's task should always be to reduce σ_ε^2 and σ_j^2. This may be attained by creating homogeneous conditions for growing (to begin with parent maintenance conditions) and reducing food competition which frequently enhances the interactional variance.

Experience over many years in selecting the Ropsha carp has allowed us to determine the conditions that may contribute to a decrease in environmental variance (Kirpitschnikov, 1959; 1960; 1961; 1966a). In many respects they are like Schäperclaus, (1961) recommendations and may be reduced to the following:

(i) grow the parents under identical conditions;

(ii) secure simultaneous spawning (using hypophyseal injection) or, still better, replace spawning by artificial fertilization of spawn and subsequent incubation in apparatus;

(iii) give the larvae excess food;

(iv) grow fingerlings as well as fish of older ages under relaxed food competition without mixing fish from different crossings;

(v) stock fish in each pond in the shortest possible time.

It must be said that in spite of observing all these conditions, the environmental variance (σ_ε^2) in carp and in many other species of pond fish proves to be very considerable. A complete elimination of causes that produce unequal conditions of life for individuals living together in ponds is impossible.

2.3.1 Selection performed not at the age when fish have market value may considerably reduce heritability. Disproportion between the growth rate of fingerlings, two-year-old and three-year-old carp has been noticed more than once (Schäperclaus, 1955; Stegman, 1965a, b; Kirpitschnikov, 1966a). Ten to 50 percent of fish selected as champions of weight in the first year of their life, cease to be champions in the second or third years. Due to the mentioned disproportion, heritability may decrease by 25 to 50 percent and more; therefore it is advisable to cull fish mainly at the age when the chosen characters are to be improved.

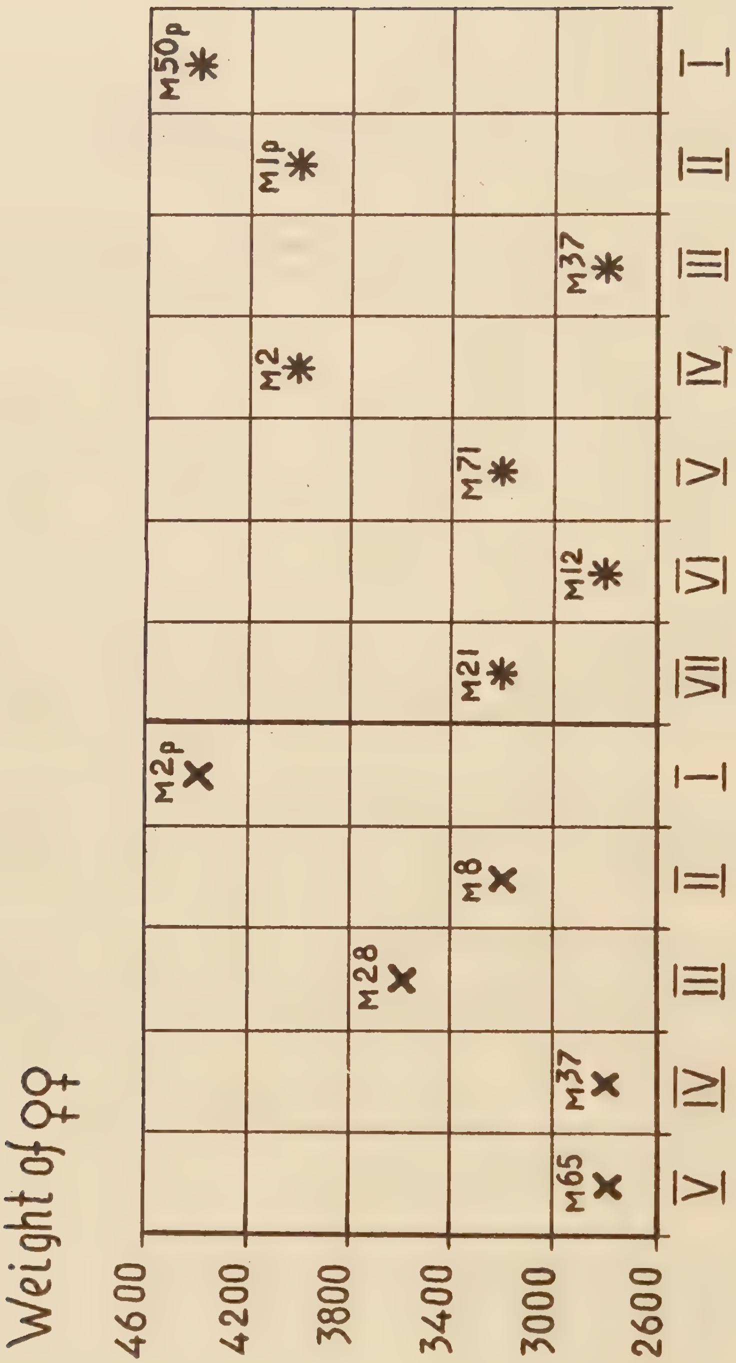


Fig. 3 Correlation between weight of females and the place occupied by their offspring in order of growing rate

Ropsha, 1960 (left) and 1961 (right)

2.3.2 Occasionally, heritability decreases because of "heterozygous balance" - a phenomenon peculiar to many species of animals and plants (Lerner, 1954). Heightened viability and accelerated growth of heterozygous individuals was revealed by us in carp (Kirpitschnikov, 1966b). Variability of quantitative characters remaining on the same level in all hybrid generations of the Ropsha carp (Kirpitschnikov, 1958) also suggests the presence of balanced heterozygosis in this case.

Due to the great number of chromosomes in carp (2n = 104) and many other food-fish, the probability of heterozygous balance being established in a population appears to be very great. Hence, it is the individuals with maximum heterozygosis that will be the most viable and fast growing in a population.

Selection under such conditions very soon becomes inefficient, since the genetic variability proves to be in the main non-additive. As to heritability of any character in a more exact (narrow) sense, it is a portion of additive genetic variability in the total variability of the given character (Lush, 1949)

$$h_2^2 - \frac{\sigma_A^2}{\sigma_{Ph}^2} \qquad (5)$$

where

$$\sigma_A^2 = \sigma_G^2 - \sigma_D^2 - \sigma_I^2 \qquad (6)$$

Without balanced heterozygosis the variances of dominance and epistasis ($\sigma_D^2$and σ_I^2) are small and virtually the additive genetic variance does not differ much from the total variance (σ_G^2). If there is a substantial heterozygous balance for many polygenes, the difference between h_1^2 and h_2^2 will be very great. A true heritability in spite of considerable genetic variability (σ_G^2) will be near 0, since the variability is not additive.

It is difficult to strive against an established heterozygous balance, as the equilibrium of genotypes proves to be very stable. The only way to correct the situation is to perform new, sufficiently remote crossings which may destroy the polygene system and thereby contribute to an increase in heritability.

In all the cases when heritability is not too low, mass selection may yield results. Unfortunately, the weight heritability in carp during the first year of life is low, probably it does not even reach 0.2 (Moav and Wohlfarth, 1963; Kirpitschnikov, 1966a; Nenashev, 1966). With age, the weight variance in carp decreases (Wlodek, 1966). The decrease evidently occurs at the expenditure of a reduction in specific gravity of the environmental variance (σ_ε^2), i.e., it is followed by an increase in heritability. A marked correlation between the weights of females and the growing rate of offspring, which we have revealed by our experiments, fits this hypothesis (Fig.3).

Two conclusions may be drawn:

(i) A selection even of the largest carp fingerlings will be of small effect if we aim at improvement in two-year-old fish.

(ii) Rate of growth in two-year-old fish may be more easily enhanced by performing selection on two-year and older fish (up to spawners). The difficulty in the latter case may arise from sex dimorphism of growth rate, as well as from the limited number of fish.

Mass selection is likely to keep its paramount importance in selection of fish, for a long time. This method is suitable for selection for growing rate and exterior improvement, when needed, the colour of skin and the scaly cover, as well as a number of other morphological characters. It can be also used partially to enhance the resistance of fish to adverse environmental influences and many dangerous diseases. Mass selection should be replaced by testing for relatives only in cases when we try to improve such characters as fat content, biochemical composition of meat, and degree of boniness, or if the principal task is to raise the fish production of ponds.

Selection for weight is always possible, but it does not always give the results one expects. In the presence of food competition, we select the more "aggressive" individuals who are able to snatch food from their neighbours in pond (Moav and Wohlfarth, 1963) but are not necessarily the best at assimilating food. It is evident that for improving the rate of growth mass selection should be combined with testing for relatives.

3 SELECTION FOR RELATIVES

Two types of testing for relatives, namely family selection (including sib selection) and progeny testing of spawners, can be used in fish culture. As in mass selection, the efficiency of selection for relatives is expressed by a simple equation:

$$R = i_f \sigma_f h_f^2 \qquad (7)$$

In this equation, intensity of selection (i_f) equals the difference between mean for selected family and population mean expressed in mean square deviations. σ_f characterizes the variability of family means, and h_f^2 characterizes heritability of differences between family means. Of course, the value σ_f is as a rule much smaller than the value of individual variability; selection intensity is also usually reduced, since the number of families is commonly restricted. Heritability of family means, on the contrary, can reach very high values if the families are grown together or under similar conditions.

Let us consider again, one after another, the possibilities of increasing each component of equation (7) in family selection and progeny testing in fish culture.

3.1 Family selection

Selection intensity (i_f) depends, to a very great extent, on the number of families. So, if there are only three families to compare, selection intensity will exceed unity by a negligible value, while with ten families it is near two. Evidently, one has to aim at a parallel testing of as many families as possible, leaving for breeding purpose only one or two of the best ones. It appears, however, difficult to increase the number of families over 10 to 12 since it requires a lot of testing ponds.

Variability of the family means (σ_f) is not great; just as in mass selection, it can be increased only at the expenditure of enlarging its genetic component. Therefore it is of great importance to perform sufficiently remote crossings before the onset of family selection.

Heritability plays the most important part in family selection. If some families have been bred under similar conditions (in the same pond or basin, or ponds of a very like character), non-genetic variability of family means can be brought to 0. Reduction in $\sigma^2_{e,f}$ can be attained by breeding families with multiple repeatability in series of ponds. As we have to deal with fish, we are able to breed large families and characterize each family on the basis of tens or even hundreds of individuals. This allows us to bring h_f^2 to a very high value and to raise the efficiency of family selection. Non-additive genetic variability associated with dominance, epistasis, and balanced heterozygosis is relatively poorly pronounced in variability of family means, and does not reduce heritability in any considerable way. The most important conditions for family selection are the following:

(i) sufficient genetic variability of family means;

(ii) homogeneity of conditions for growing separate families, or sufficient reiteration of experiments.

In practice, family selection is profitable in all cases when a decrease in selective differential (at the expenditure of reduction in selection intensity and variability) is compensated by raised heritability:

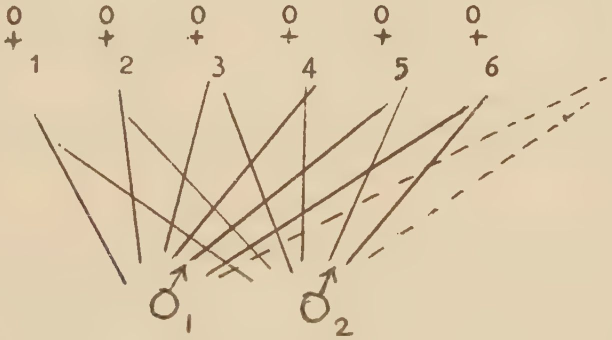
$$h_f^2 - h^2 > S - S_f \qquad (8)$$

As in family selection in carp culture, growing of ten families from which two are left for breeding (selection ratio = 1:5; v = 20 percent) corresponds to $i = \sim 1.5$; in mass selection i may be easily brought to 3. Variability of family means, according to our observations (see below), is three to five times lower than individual variability. Hence the selective differential in family selection is six to ten times lower than that in mass selection. Even if we take h_f^2 as unity, a replacing of mass selection by family selection will not be profitable unless heritability of the character is extremely low ($h^2 < 0.1 - 0.15$). In cases where only a small number of fish can be grown, and thus i in mass selection decreases to 1.5 - 2, family selection will be more desirable even with a greater value of h^2 (up to 0.3 and occasionally > 0.3). It concerns also the cases when spawners used for obtaining families are genetically quite heterogenic, and the difference between σ^2 and σ_f^2 is small.

On the contrary, if the family breeding value is not well enough determined and hence h_f^2 is reduced to 0.8 or even 0.7 - 0.6 or smaller values, mass selection should be preferred.

3.2 Progeny testing

Progeny testing enables us to appraise at its true worth the breeding qualities of separate spawners. As has been shown by our experiments, the best results are obtained by testing spawners of either sex making use of artificial insemination according to the scheme of polyallele crossing:



The number of spawners to be tested may be brought to 10 to 12. Crossing should be always performed with two males (or females) simultaneously; hard-roe or soft-roe taken from two spawners can be mixed in such cases to use the same mixture in all crossings.

The main drawback of progeny testing is in its being time consuming. At first we tried to test spawners for growth rate and larval survival but it was found to be impracticable. Male testing is disturbed by the so-called "paternal effect", the larger males having better sperm and the quality of sperm exerting an influence upon survival and growth offspring in the first phases of their development. In female testing, there is displayed, to a still higher degree, the "maternal effect", the influence of the egg size upon larval survival and growth. The maternal effect was observed in all our experiments on female

Table II

Progeny testing of carp females. Ropsha, 1960

Weight of 7-year-old females g	Average weight of unfertilized eggs in ovulation mg	Loss of eggs and larvae before active feeding %	Average weight of larvae, mg			Weight of fingerlings experiments			Weight of two-year-old fish
			5 day	30 day	38 day	1	2	3	
3,060	0.88	19.4	1.75	66.6	208	11.8	5.4	5.9	392
3,730	0.97	18.5	1.98	64.9	188	10.6	4.7	5.7	380
2,680	1.15	12.9	2.22	72.2	199	12.2	5.2	5.5	365
2,890	0.99	19.0	1.78	60.4	285	10.3	4.4	5.3	388
4,200	0.76	28.5	1.60	63.3	182	13.2	6.1	6.1	430

Table III

Progeny testing of carp females. Ropsha, 1961

Weight of 7-year old females g	Average diameter of fertilized eggs mm	Loss of eggs and larvae before active feeding		Larval weight		Place of fingerlings in control experiments		
		♂K %	♂M9 %	5 days mg	30 days mg	1-3 exper.	4-5 exper.	6-8 exper.
4,160	1.32± +0.02	26.6	30.0	2.09	108.3	I	I	I-II
4,500	1.28± ±0.02	19.6	36.0	1.74	103.3	II	II	I-II
4,150	1.17± ±0.02	46.2	50.1	2.09	101.9	III	V	III-V
2,910	1.33± ±0.02	61.0	64.5	2.35	97.3	V-VII	VI-VII	VI-VII
3,360	1.24± ±0.02	32.7	51.0	2.09	98.2	V-VII	VI-VII	VI-VII
2,850	1.39± ±0.03	33.3	35.6	2.23	108.7	IV	IV	III-V
3,190	1.31± ±0.03	24.5	30.9	1.89	100.6	V-VII	III	III-V

testing (Table II and III); it disappeared only when the weight of fingerlings reached two to three g. It is only by comparison of fingerlings or even two-year-old fish that we can detect the actual breeding differences between spawners. Their objective testing requires, consequently, one or two years and only after that period of time are we able to utilize the selected spawners (champions) for reproduction.

Let us consider, by means of the above formula for selection efficiency (7), what the advantages of progeny testing are.

Just as in family selection, the intensity of selection is limited by the number of families. If there are 10 to 12 families from which we chose two as the best ones, $i = \sim 1.5$ i.e. it has the same value as in family selection.

Variability of family means (σ_f) is also about the same in both cases. In progeny testing it is slightly reduced since only spawners of one sex differ in families under test.

Progeny testing of spawners performed during the work with Ropsha carp has allowed us to calculate relative values of σ and σ_f (Table IV). The weight variation coefficient for carp fingerlings obtained from a group of spawners normally amounts to 25 percent, for two-year-old fish it does not exceed 20 percent (Kirpitschnikov, 1961; Wlodek, 1966). For this reason we have calculated the maximum values of σ_{ind} to include them in the Table. The ratio of individual weight variability to variability of family means, varies within 2.0 to 4.9. We may assume it to average 3 to 4. So, progeny testing will be profitable if heritability in the test is about 6 to 8 times greater than that in mass selection. In other words, progeny testing proves to be advantageous, if h^2 in mass selection does not exceed 0.1 - 0.15.

Thus, heritability of family means (h_f^2) in progeny testing, just as in family selection, must be very great, near to unity.

This may occur only if breeding conditions of all progenies are practically identical, or if breeding proceeds with a three-or four-fold reiteration. The main drawbacks depend on long-term experiments required. Under the climatic conditions of the north-western U.S.S.R. offspring should be maintained for one to two years. A drop in selection rate with which this is associated reduces even more the efficiency of progeny testing to make it practically insignificant. The use of this method is indispensable only in cases when mass selection cannot be applied due to particular features of the character concerned.

4 COMBINED SELECTION

In animal breeding, selection for relatives, especially for offspring, has been rising more and more in importance in recent years. In fish breeding, mass selection, as we have stated, appears to be more efficient than selection for relatives because of high fertility of fish. At the same time this second method possesses some substantial advantages, in particular it is less subject to accidental variations.

To correct this situation we may resort to combined selection which includes the following stages (Fig. 4):

(i) performing mass selection among fingerlings or two-year-old fish with a great severity coefficient;

(ii) progeny testing of males through all the time of their coming to maturity, since males of most fresh-water fish mature before females (in the Ropsha carp the difference amounts to two years);

(iii) family selection with a simultaneous breeding of 5 to 10 families, champions detected in experiments with progeny testing of spawners being used as males;

(iv) in the best families, repeated performance of mass selection.

Table IV

Individual and family weight variability of fingerlings and two-year-old carps in progeny testing of spawners.
Ropsha, 1960-1961

Year	Pond	Weight total mean g	Weight variation of means	σ_f observed g	σ_{ind} observed g	calculated with C = 25% g	calculated with C= 20% g	Ratio $\frac{\sigma_{ind}}{\sigma_f}$
	Fingerlings (1960)							
1960	1st experiment	11.60	10.3- -13.2	1.21	2.25	2.90	-	2.4
	2nd experiment	5.15	4.43- -6.05	0.63	1.09	1.29	-	2.0
	5th experiment	5.67	5.27- -6.07	0.32	0.93	1.42	-	4.4
	6th experiment	4.51	4.19- -4.80	0.23	0.70	1.13	-	4.9
	Two-year-old fish (1961)							
1961	Zrekinsky I	391	365-430	24	71	98	78	4.1

σ_f = mean square deviations of family means(five families in every pond)

$\sigma_{ind.}$ = mean square deviations in all individuals of all families of a given pond

C = variation coefficient of individual values.

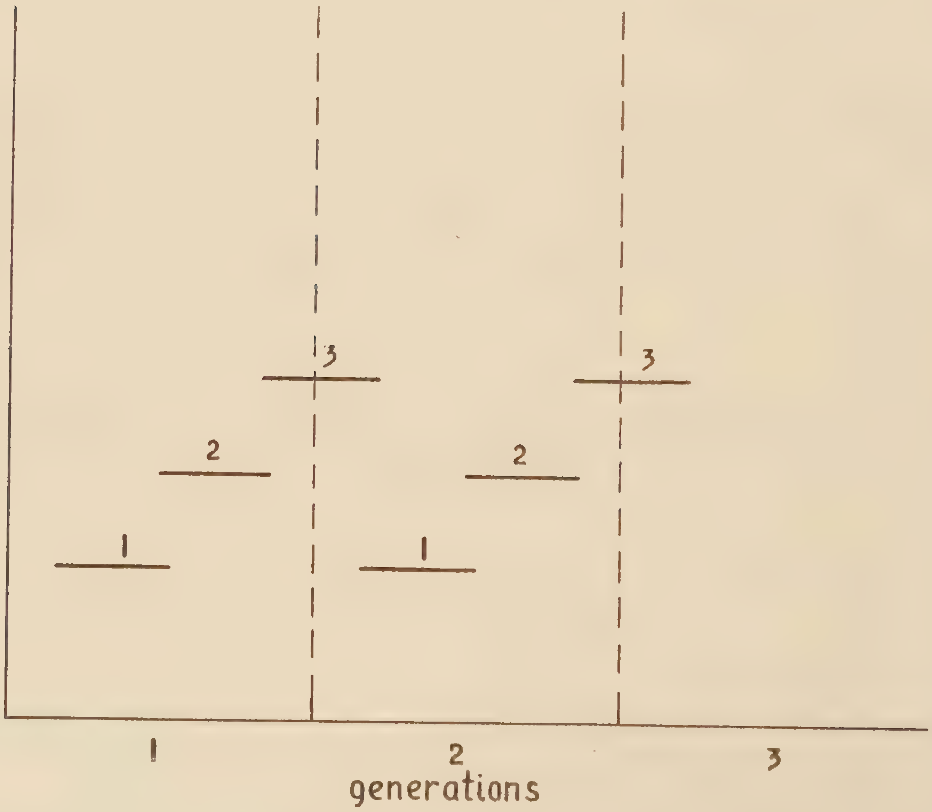


Fig. 4 Scheme of combined selection for improvement of the Ropsha carp

(i) mass selection in the 1st and 2nd years of life;
(ii) progeny testing of males at the age of 2-4 years;
(iii) family selection with use of spawners at the age of 5-6 years.

Such a scheme of selection allows summing up of the efficiency of mass selection and selection for relatives without waste of time. At present this scheme is being tried on the Ropsha hybrid carp.

5 CONCLUSIONS

(i) To enhance the efficiency of mass selection we have to increase, as much as possible, the value of three factors: intensity of selection, variability, and heritability of the character we are selecting.

(ii) Increase in heritability is the most important, as the other two factors vary within a comparatively small range. Heritability may be increased by means of crossings, creation of homogeneous conditions for maintenance of fish, and carrying out selection at the age to be improved. Most dangerous is a reduction in heritability in the presence of balanced heterozygosis for polygenes, i.e. in the presence of the so-called genetic homeostasis. Only crossing alone can upset this balance.

(iii) Family selection and progeny testing in fish breeding prove to be more efficient than mass selection only in case of a very low heritability of the character ($h^2 < 0.1 - 0.15$). The main difficulty in performing selection for relatives consists in technical intricacy which occurs when the growing of a sufficiently large number of families under identical conditions is required.

(iv) Much benefit may be expected from combined selection in the course of which mass selection, progeny testing of males, and family selection are performed successively in one generation.

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METHODS OF BREEDING THE GRASS CARP, *CTENOPHARYNGODON IDELLA* AND THE SILVER CARP, *HYPOPHTHALMICHTHYS MOLITRIX*

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Abstract

In stagnant ponds the grass carp (*Ctenopharyngodon idella*) and the silver carp (*Hypophthalmichthys molitrix*) can reach maturity and retain high growth rate. They can be induced to breed with the aid of hypophysial injections and the adoption of this breeding technique enables these carps to be cultured on a commercial scale. However, it is clear that the technique requires further improvement.

Fractional injections of hypophysis were found to be most effective in accelerating maturation.

Artificial breeding of these carps yields parasite-free stocks.

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METHODES D'ELEVAGE DE LA GRASS CARP, CTENOPHARYNGODON IDELLA ET DE LA SILVER CARP, HYPOPHTHALMICHTHYS MOLITRIX

Résumé

Dans les étangs d'eau stagnante la grass carp (Ctenopharyngodon idella) et la silver carp (Hypophthalmichthys molitrix) peuvent atteindre la maturité et conserver un taux de croissance élevé. On peut provoquer leur reproduction à l'aide d'injections d'extrait hypophysaire et l'adoption de cette technique permet l'élevage de ces carpes sur une échelle commerciale. Toutefois, il n'est pas douteux que la technique demande à être améliorée.

Il a été constaté que ce sont des injections de fragments d'hypopyse qui donnaient les meilleurs résultats pour accélérer la maturation.

La reproduction artificielle de ces carpes permet d'obtenir des populations exemptes de parasites.

METODOS DE CULTIVO DE LA CARPA HERBIVORA, CTNOPHARYNGODON IDELLA Y DE LA CARPA PLATEADA, HYPOPHALMICHTHYS MOLITRIX

Extracto

En masas de aguas estancadas la carpa herbívora (Ctenopharyngodon idella) y la carpa plateada (Hypopthalmichthys molitrix) pueden alcanzar la madurez y mantener un elevado ritmo de crecimiento. Se puede practicar la reproducción forzada mediante la ayuda de inyecciones hipofisarias, y la adopción de esta técnica de reproducción permite el cultivo de estas carpas en escala comercial. No obstante, es evidente que la técnica exige ser perfeccionada.

Se comprobó que para acelerar la madurazión eran más eficaces las inyecciones hipofisarias en cantidades pequeñas.

La reproducción artificial de estas carpas permite la obtención de poblaciones libres de parásitos.

1 BIOLOGICAL CHARACTERISTICS OF PHYTOPHAGOUS FISHES

Of all the phytophagous fishes of the U.S.S.R. only the grass carp, Ctenopharyngodon idella, and the silver carp, Hypophthalmichthys molitrix are significant in commercial fisheries. Both these species are known to occur in the Amur River, the northern boundary of their distribution.

C. idella is a quick-growing fish attaining more than 30 kg in body weight. For a month and a half its fry feed on animal food, mostly zooplankton. As soon as fingerlings are 3 cm long, they become phytophagous. C. idella lives on higher aquatic plants including soft submerged vegetation, young seedlings of semi-submerged water plants and meadow plants submerged in high floods. Besides higher plants, the grass carp willingly feeds on filamentous algae.

H. molitrix is another rapidly growing fish which reaches the weight of more than 16 kg. Unlike the grass carp, this species feeds on lower aquatic plants, i.e. microscopic planktonic algae filtered by the gill apparatus. The gill rakers of the silver carp make a fine-meshed sieve which serves to collect the phytoplankton entering the oral cavity.

The fry of the silver carp at first feed on zooplankton, and only when the fingerlings reach the length of 12 to 17 mm do they become plant-feeders. Adult specimens eat phytoplankton almost exclusively. However, when phytoplankton is not available, they may feed on detritus.

For feeding, phytophagous fishes enter numerous flood-plain lakes in the basins of Amur and some Chinese rivers. In autumn, during the abatement of the river and fall of temperature, both the grass and silver carp migrate toward the river bed where they hibernate and usually cease feeding (Verigin, 1963).

In spring, mature fish migrate to areas with swift currents for breeding. Spawning begins when the water temperature is about 20°C. Besides the temperature factor, spawning in both species is influenced by fluctuations in the river level. Japanese investigators think that the onset of spawning is determined by water level changes, and that the temperature factor plays a subordinate role in the process (Sudzuki et al., 1962; 1963).

In the rivers of South China both species attain sexual maturity at the age of three or four years. Further to the north plant-eating fish mature later. Thus in the basin of the Yangtze river the silver carp matures for the first time at the age of four years, and the grass carp at the age of five or six years. In the Amur both species mature even later (Makeeva, 1963).

In the Chinese rivers spawning of both species takes place at the same time, but only a part of the stock spawns at a time. This is why the spawning period is rather extended, lasting from the middle of April to August. In the Amur river, according to Makeeva (1963), specimens occur with asynchronous vitillo-genesis, indicating that the same female may spawn twice during one growing season.

An unfertilized egg is on average 1.16 mm in diameter, but on swelling, the initial volume increases from 45 to 100 times. The swelling capacity is also retained in unfertilized eggs. Depending on the temperature, the incubation period lasts for 20 to 40 hours. Hatched larvae are at first carried passively downstream and afterwards concentrate along the shoreline. For feeding they migrate to the system of flood-plain lakes.

2 METHODS OF ARTIFICIAL BREEDING

Rapid growth and the habit of feeding on macrophytes and phytoplankton were the reasons for breeding the grass and silver carps. The intensive development of fisheries, particularly over the last ten years, required stocking material in amounts not available in natural water bodies. Therefore, the artificial breeding of these species was considered to be the primary task for fish breeders.

In the Soviet Union the breeding of the grass and silver carps was tried in nursery ponds. Because of the absence of an established technique for artificial breeding, large quantities of fry were imported from the Far East and China to the European part of the U.S.S.R. However, together with the carp fry there came some undesirable trash fish, and even some dangerous parasites which did not occur in our water bodies. A very complicated system of quarantine and the dependence of our fishery managements on the yield of larvae of these fishes from natural waters greatly handicapped their culture.

Numerous attempts to induce breeding in special ponds, imitating natural spawning conditions, failed. Later work concentrated on the stimulation of maturing gonads with hormonal preparations. In 1959 Soin (1959) took part in the work carried out on the Sungari River in China to obtain sexual products of the silver carp. There he obtained commercial quantities of the silver carp larvae from spawners which had reached maturity in natural water bodies. Despite this success, the use of hypophysial gonadotrophic hormone for breeding these fishes did not yield encouraging results. Very frequently the injected spawners did not attain sexual maturity, or the eggs failed to develop.

The present communication describes the experiments in the breeding of these carps in which the author participated. The method of hypophysial injections developed by Gerbilskii and his collaborators in 1939 (Gerbilskii, 1941), was followed in this work.

As mentioned above, the spawning stocks of grass and silver carps include specimens which are not equally ready for spawning. Therefore, we based our work on the suggestion of Gerbilskii that fractional injections of hormone might be effective on not-quite-mature females (Gerbilskii, 1959). Kasanskii (1960) had successfully applied fractional injections in his work with sevruga (Acipenser stellatus).

It is known that in China in order to obtain eggs from these phytophagous fishes, fish-breeders use very large dosages of gonadotrophic hormone (Soin, 1959). The purpose of our initial experiments was to determine the normal dosage and the results obtained are given in Table I.

Table I

Results obtained from applications of high and threshold doses of hypophysial injections to the silver carp

Variants	Number of females	Dose of hormone in mg	Number of mature females	Quality of eggs obtained
I	13	24	3	Not developed
II	4	8	1	71% developed
III	4	12	1	50% developed

Although large doses of gonadotrophic hormone induced ovulation, they greatly affected the quality of eggs and these failed to ripen. The dosage of hormone approaching the threshold dose yielded satisfactory eggs but only a very low percentage of ripe females. It was necessary to find an injection procedure to obtain eggs of good quality and at the same time a high percentage of ripe spawners. The comparison of several variants of fractional and single dose injections permitted the solution of this problem. Table II gives the results of experiments with silver carp.

As a result of further work it was possible to reduce the dose of the first stimulating injections, compared with the second, reducing it to as low as one-seventh and one-eighth of the initial value.

Similar work was done on the grass carp and the main ways of inducing maturation in this species proved to be the same as in the silver carp (Table III). The experiments with silver carp and with grass carp showed the advantage of fractional injections in comparison with single dose injections.

At present fractional injections are widely used in the U.S.S.R. and are applied in all fish farms, where grass and silver carps are reared (Aliev, 1961; 1963; Vinogradov, *et al.*,1963).

Table II

Results obtained by single dose and fractional hypophysial injections of the silver carp

Variants	Number of females	Dose of hypophysis in mg	Number of mature females	Quality of the eggs obtained
		Single dose injection		
I	4	12	1	15% developed
II	4	20	1	Not developed
		Fractional injection		
I	10	2 + 18	4	80% developed
II	2	6 + 12	1	80% developed
III	9	2 + 10	9	in 8 females more than 80% of development. In one female eggs were over-ripened

Notes: Water temperature - 18-20°C. Intervals between injections - 24 hr. The weight of female - 9 - 10 kg.

Table III

Results obtained by single dose and fractional hypophysial injections of grass carp

	Number of females in experiment	Dose of hormone	Number of mature females	Number of thousands of eggs per female	Percentage of development of eggs
One dose injection					
I	2	28	0	0	0
II	5	28	3	52	28.5
Fractional injection					
I	20	4 + 28	14	785	55.8
II	14	4 + 28	14	470	58.6

Notes: The dosage of dry hypophysial substance was determined by the number of hypophyses taken for the injection of one female. The average weight of a hypophysis was 4 mg.

The average weight of a female was 7.5 kg. The interval between injections was 24 hours. Water temperature for experiment I was 24.0°C, and for II 24.2°C.

In order to determine an optimal interval between two injections we tried to make the second resolving injection 12 hours after the first stimulating one. A total of eight females of the silver carp were injected in this way. In all the specimens under investigation we observed incomplete maturity. On an average in these experiments one female yielded no more than ten thousand eggs.

The time required for the ripening of sexual products after the resolving injection was experimentally determined. When the temperature ranged from 20 to 24° it was 10 to 13 hours.Sometimes on our first attempt to strip the eggs a female yielded them only in small batches. In such cases an hour later we had to repeat the operation with the same female. Separate incubation of the first and second batches of eggs allowed the conclusion that a delay in shedding eggs had a negative effect on the percentage developing. The analysis of the evidence obtained is given in Table IV.

For artificial breeding of grass and silver carps, the dosage of gonadotrophic hormone should be chosen according to whether injections are made at the onset or by the end of the spawning season. The dependence of egg quality on the date of treatment and dosage of hypophysial hormone is shown in Table V.

Table IV

Delay in ovulation of a mature female of the grass carp and its effect on the quality of eggs

No.	Water temperature °C	Duration of delay hr	Weight of fish in kg	Number of thousands of eggs	Percent of development
1	23.6	1.5	7.5	31.2	86.5
2	22.8	2.0	7.5	100.0 280.0	57.0 77.0
3	23.2	1.0	6.8	200.4 280.1	65.2 23.7
4	24.4	1.0	8.0	213.0 273.2	90.6 85.0
5**	24.3	1.0	7.0	113.4 23.7	10.7 1.9
6	24.3	1.0	9.3	102.5 133.6	84.6 81.2
7	24.5	3.0	8.2	300.1 27.1	77.0 51.3
8	23.8	3.0	6.0	46.8 537.2	81.1 73.6

**The female received a single dose injection of 28 mg dry weight of hypophysial substance of the wild carp (Cyprinus carpio)

Table V

Changes in the quality of eggs of grass carp depending on the date of treatment and dosage of gonadotrophic hormones

Date	Number of females	Number of mature females	Average weight of female kg	Hormone dose mg	Maturation time hr	Number of eggs per female	Average % of development
13.6.65	10	7	7.8	4 + 28	12	515,000	67.0
16.6.65	20	12	7.6	"	12	434,000	85.0
18.6.65	21	12	7.3	"	12.5	441,000	57.5
20.6.65	17	9	6.9	"	13	487,000	40.0
22.6.65	17	15	7.4	"	12	477,000	69.3
24.6.65	20	14	6.9	"	12	783,000	60.0
26.6.65	19	17	7.3	"	11.5	603,000	58.0
28.6.65	20	17	7.8	"	11	396,000	57.0
30.6.65	20	14	7.2	"	9.5	495,000	27.9
2.7.65	20	14	7.5	2 + 20	8.0	460,000	70.3
4.7.65	19	12	7.2	"	7.2	476,000	87.0
6.7.65	19	10	7.1	"	7.5	601,000	65.0

A gradual decrease in the quality of eggs for the period from 13 to 20 June probably may be explained as follows: first, we did not take into account the fact that a gradual increase in the water temperature reduced maturation time of females after injections. Therefore in the middle and by the end of June over-ripening of eggs in the body of a female produced an unfavourable effect. Secondly, in the middle and by the end of the work spawners were found to be more mature than at the beginning, and the sensitivity of the fish to the effect of gonadotrophic hormone increased. Due to this fact, the doses applied were too high, which deteriorated the quality of the eggs. A decrease in the dosage and earlier examination of spawners after the final injection (after 30 June) eliminated the effect of these unfavourable factors and sharply increased the quality of eggs (see Table V). The results of the work discussed show that there is still much to be done to find out all the peculiarities in the effect of gonadotrophic hormone on the ripening of eggs of these fishes.

Tables I, II and III demonstrate the increase in the doses of hypophysial gonadotrophic hormone applied for injections. From these tables it might be thought that the grass carp requires somewhat larger doses of hormone than the silver carp. However, this is not so. Fishes of the same weight of the two species attain ripeness from equal amounts of the hormone injected. The above tables illustrate the experiments conducted at different times and with hypophyses taken from fishes of various sizes. Hypophyses collected at different times differed in their weight and activity. The normal dosage for each series of hypophyses was determined experimentally. Here, however, we do not give the results of these experiments, for they are of no principal significance. It must be pointed out that determinations of dosage (in mg of the dry hypophysial substance) are not exact. Therefore it is difficult to compare the results obtained from experiments with different series of hypophyses.

It seems more reasonable to express hypophysis activity in biological units, e.g. in Misgurnus units (M.U.) (Kasanskii, 1949).

3 TECHNIQUES USED FOR THE BREEDING AND REARING OF GRASS AND SILVER CARPS

During the last five years the practice of artificial breeding of grass and silver carps has been successfully developed in the U.S.S.R. At present our fish farms yield annually more than 150 million larvae of these fishes. Taking into consideration the value of these species and the great interest that foreign fish-breeders have in them, it is useful to summarize the principal techniques adopted for breeding and rearing of larvae.

The grass and silver carps reared in stagnant ponds attain sexual maturity. In the southern regions of the U.S.S.R. maturity in both species occurs at the age of at least five years. Work on obtaining eggs should be started not earlier than when the water temperature is 20°C. Eggs and milt are obtained by means of hypophysial injections. For this purpose the females of both species are treated with fractional injections of wild carp hypophysial suspension. Males are treated with single dose injections (Konradt, 1961). The purpose of the first injection is to stimulate preovulation nuclear changes in the ovocytes, and is therefore only a stimulating injection. Its dosage should be quite insignificant not to induce ovulation in mature spawners. About 2 to 4 mg of dry hypophysial substance is sufficient for a stimulating injection. Nuclear rearrangements are completed 12 to 20 hours after this injection. That is why the second injection which must cause ovulation is made 24 hours after stimulation. The second injection is called resolving and its dosage is 7 to 10 times as high as that of the stimulating one (Vinogradov, et al., 1963). We used 20 to 35 mg of hypophysial substance. Depending on the temperature, ovulation appears to be completed 8 to 13 hours after the injection.

Eggs are fertilized by milt not diluted in water (1 - 1.5 cm^3 milt per litre of eggs). After mixing the eggs with the milt, water is added. Then the mixture is allowed to stand for 10 to 15 minutes, and during this time it is shaken slightly. After this it is placed in a Weiss apparatus (eight litre) with a capacity for 50,000-70,000 eggs. A water current of 0.6 - 0.7 litre per minute is required for a standard apparatus.

Hatched larvae are very agile and, therefore, they are carried out of the apparatus by the stream of water into special larvae traps of fine gauze netting (No.15-19). Then they are scooped out together with water and put into stews made of the same fine gauze netting and installed in ponds. The oxygen concentration of the water in the stew should be not less than four mg per litre.

Stews must be protected against small trash fish, for the latter can suck larvae out through the walls of the stew. On the fourth or fifth day the larvae begin to feed on the fauna around and swim freely in the depth of water. Now they can be released into ponds for rearing or delivered to other fish farms.

Larvae are transported in special plastic bags filled with oxygen. One end of the bag is sealed off, while the other is hermetically closed with a clamp. The ratio of the water and oxygen in the bag is 1 : 1, and stock density 2,000 - 4,000 per litre. The technique of larvae transportation was worked out and reported by the Central Acclimation Station of the U.S.S.R.

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SOME RESULTS OBTAINED BY THE HYBRIDIZATION OF CYPRINIDS

by

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Abstract

The crossing of the European cultivated carp (*Cyprinus carpio*) with the Amur wild carp belonging to different subspecies of *C. carpio* causes heterosis in growth rate and viability which are strongly pronounced at early development stages. Under favourable maintenance conditions (low temperature, starvation) the advantage of hybrids is most evident.

The percent of fertilization in the hybrids obtained from the crossing of the grass carp (*Ctenopharyngodon idella*) with the silver carp (*Hypophthalmichthys molitrix*) or the bighead (*Aristichthys nobilis*) is not lower than in the parental forms. Some of the hybrid combinations inhibit high survival rate; the larvae of the three hybrids (GB, GS, SB) were found to be larger than parental forms.

A morphological study of the hybrid obtained by the crossing of the grass carp with the bighead has shown that in some properties it is an intermediate form. The structure of the filtering apparatus evidently shows a wider feeding spectrum for the hybrid in comparison with the bighead.

IV/E-10

CERTAINS RESULTATS OBTENUS EN MATIERE D'HYBRIDATION DES CYPRINIDES

Résumé

Le croisement de carpes européennes d'élevage (Cyprinus carpio) avec des carpes sauvages de l'Amur appartenant à différentes sous-espèces de C. carpio entraîne, en ce qui concerne le taux de croissance et la viabilité, une heterosis très marquée aux premiers stades du développement. Dans des conditions d'élevage défavorables (température basse et alimentation insuffisante) l'avantage des hybrides est manifeste.

Le pourcentage de fécondité chez les hybrides obtenus par croisement de la "grass carp" (Ctenopharyngodon idellus) avec la "silver carp" (Hypophthalmichthys molitrix) ou la "bighead" (Aristichthys nobilis) n'est pas inférieur à celui des parents. Avec certains croisements on ne peut obtenir un taux de survie élevé; il a été constaté qu'avec les trois hybrides (GB, GS, SB) les larves étaient plus grosses que dans les races d'origine.

Une étude morphologique de l'hybride obtenu par croisement de la "grass carp" avec la "bighead" a montré que, pour certaines caractéristiques, il s'agit d'une forme intermédiaire. La structure de l'appareil de filtrage indique de toute évidence que l'hybride possède un spectre alimentaire plus étendu que celui de la "big head".

ALGUNOS RESULTADOS OBTENIDOS CON LA HIBRIDACION DE CIPRINIDOS

Extracto

El cruzamiento de la carpa cultivada europea (Cyprinus carpio) con la carpa silvestre del Amur perteneciente a diferentes subespecies de C. carpio determina heterosis en el ritmo de crecimiento y en la viabilidad que son fuertemente pronunciadas en las primeras fases del desarrollo. Bajo condiciones de mantenimiento desfavorables (baja temperatura, deficiente alimentación), la ventaja de los híbridos resulta más evidente.

El porcentaje de fertilización en los híbridos obtenidos del cruzamiento de la carpa herbívora (Ctenopharyngodon idellus) con la carpa plateada (Hypophthalmichthys molitrix) o la de cabeza grande (Aristichthys nobilis) no es menor que en las formas progenitoras. Algunas de las combinaciones híbridas impiden un elevado coeficiente de supervivencia; las larvas de los tres híbridos (HC, HP, PC) se observó que eran de major tamano que las formas genitoras.

Un estudio morfológico del híbrido obtenido por el cruzamiento de la carpa herbívora con la de cabeza grande ha demostrado que en algunas propiedades aquél constituye una forma intermedia. La estructura del aparato filtrante evidentemente muestra un espectro de alimentación más amplio para el híbrido respecto al de la carpa de cabeza grande.

1 INTRODUCTION

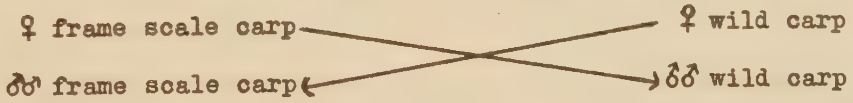
Inter- and intra-specific hybrids of fish with frequently occurring heterosis (high growth and increased survival) have practical importance in fish culture. Hybridization is often accompanied by an increase in the feeding spectrum and in the ability to find food. Some hybrids of the genus Coregonus, due to these features, can use to the full extent the food resources of the water body, and thus expand their adaptive capacities. The hybrid *Coregonus albula* x *C. lavaretus ludoga* is a valuable food fish (Lemanova, 1965).

During recent years the hybrids of the carp (*Cyprinus carpio*) and the Amur wild carp have been produced on a large scale in central, north-western and western regions of the U.S.S.R. Utilization of the hybrid carp allowed carp rearing to spread as far north as latitude 60° North (Kirpitschnikov, 1960).

Heterosis was first revealed when crossing the carp with the Volgo-Caspian and Taparavan wild carp (Kirpitschnikov and Balkashina, 1935; Saveljev, 1939). Hybrids showed high growth rate and increased viability and the number of monstrosities was considerably reduced. Later on, best results were obtained by crossing the European cultured carp (*Cyprinus carpio carpio*) with the Amur wild carp (*Cyprinus carpio haematopterus*), the East-Asiatic sub-species.

2 EXPERIMENTAL STUDIES

In 1959 we performed a series of experiments in order to study the survival, growth and variability of hybrids obtained by crossing the frame scale carp with the Amur wild carp (Andriasheva, 1966a). The material for the experiment was obtained by means of artificial insemination. Crossings were carried out simultaneously, according to the scheme which made it possible to compare the carp (c x c) with one of the reciprocal hybrids (c x w), and the wild carp, with the other (w x c):



Strong heterosis in survival was observed in these hybrids at early stages of development (Table I).

Table I

Survival of the first generation hybrids
of frame scale carp and Amur wild carp

Variants of crossing[1]	Initial number of eggs	Number of repetitions	Percentage mortality			
			Embryonic period	Hatching stage	Larvae before active feeding	Total
w x w	2,838	3	16.3 ± 0.69	16.1	27.6	60.0 ± 0.89
w x c	2,815		14.1 ± 0.64	11.7	15.4	41.2 ± 0.89
c x c	3,340	4	19.3 ± 0.68	19.7	41.8	80.8 ± 0.70
c x w	3,302		18.5 ± 0.68	19.3	29.0	66.8 ± 0.82

[1] w - wild carp; c - frame scale carp; female is mentioned first in each cross

Table II

The effect of temperature on the growth of hybrids of the first generation after crossing frame scale carp with Amur wild carp

Indices	Control 15-30°C				Experiment 12-15°C				
	1 Repetition		2 Repetition		1 Repetition		2 Repetition		
	C x W	C x C	C x W	C x C	C x W	C x C	C x W	C x W	C x C
Average weight at catching M±m (mg)	469.4 ± 24.1	510.8 ± 27.4	616.6 ± 24.6	645.3 ± 26.1	62.8 ± 2.8	47.6 ± 2.8	53.9 ± 3.0	63.8 ± 2.9	47.4 ± 2.6
% variability	36.3	33.7	29.3	27.1	32.4	40.3	37.9	31.0	38.3
Total increment (g)	21.92	19.92	23.35	22.24	3.17	2.10	2.39	2.92	2.22
Total increment (%)	110.0	100	104.9	100	150.9	100	107.6	131.1	100
Number of fishes at catching [1]	49	40	49	45	53	47	47	48	50

[1] The number of fishes and their weight at stocking was found to be identical in the combinations compared

2.1 Effects of temperature and feeding on the survival and growth of frame scale and wild carp hybrids

The hybrids showed an advantage over the parental species which was especially marked when the fishes were kept in unusual conditions (decreased temperature, different food supply, etc.). In experiments with decreased temperatures we used the frame scale carp and hybrids of the combination (c x w). At normal temperatures (15° to 30°C) and reduced temperatures (12° to 15°C) the mortality of larvae during the experiment (60 days) was:

Temperature	15°-30°C	12°-15°C
Hybrid c x w	0.8 ± 2.3 percent	21.9 ± 2.6 percent
Frame scale carp c x c	26.4 ± 4.4 percent	58.9 ± 5.5 percent

Distinct differences were also revealed in the growth rate (Table II).

Both in the experiment and control the total increment of hybrids was higher than that of the pure-bred carp. At low temperatures this difference was greater. Moreover considerable individual differences were noted in the increase of weight. At the lower temperature the hybrids were less variable in their weight than the pure-bred carp. This suggests that during the process of development the hybrid form is less dependent on temperature conditions for growth than the frame scale carp.

The wild carp and hybrids of the combination (c x w) were used in experiments with different feeding regimes (Table III).

Table III

The effect of insufficient feeding on the growth and survival of hybrids of the first generation[1]

Ropsha, 12 June - 15 August, 1959

	Type of crossing	Number of fishes		Average weight		Percentage variability
		Stocking rate	Fish output	M ± m (mg)	%	
Fasting	w x w	600	140	148.0 ± 8.3	100	63.5
	w x c	600	158	187.0 ± 10.0	126	67.5
Control	w x w	75	23	502.8 ± 51.9	100	48.9
	w x c	75	29	572.8 ± 49.8	114	43.5

[1] The hybrids and the wild carp were grown together. To enable identification, the hybrids were labelled with radioactive calcium (ca^{45})

In the experimental variant with insufficient feeding (fish stocked at a high rate) the hybrids demonstrated a greater advantage in growth rate than in the case of abundant feeding (lower stocking rate). Co-efficients of weight variability at fasting increased sharply, but the hybrids proved to be no less variable than the carp. Perhaps this may be explained by the fact that some jumpers which are, due to heterosis, more capable of standing competition, appear among the hybrids, and in the long run this results in the increase in the variability of the whole population (Krjazheva, 1965).

The experiments have therefore shown that there is heterosis in all the cases of crossing the carps of two geographically remote subspecies, European and East-Asiatic. This effect was most strongly pronounced at early stages of development. At later stages (one to two months) the advantage of the hybrids was seen only when alevins of the combinations under comparison were kept in unfavourable conditions.

2.2 The producing of phytophagous Chinese carp hybrids

Since the 1950s fishes of the Chinese plain river complex have been acclimatized in the U.S.S.R. For practical purposes it was of interest to study possible ways of obtaining hybrids between different species of phytophagous fish and, in the case of successful crossbreeding, to investigate the features of these hybrids. We made such an attempt in the summer of 1965 in Tzimljanskoje hatchery nursery farm, not far from Bolshoye Tzimljanskoje Vodokhranilistche (Andriasheva, 1966 b).

For crossing we used the grass carp (Ctenopharyngodon idella), the silver carp (Hypophthalmichthys molitrix) and the bighead (Aristichthys nobilis) imported in 1959 from China. We obtained parental forms of the grass carp (GG), silver carp (SS) and the following intergeneric hybrids:

hybrids of grass carp	x	silver carp	(GS)
hybrids of silver carp	x	grass carp	(SG)
hybrids of grass carp	x	bighead	(GB)
hybrids of bighead	x	grass carp	(BG)
hybrids of bighead	x	silver carp	(BS)
hybrids of silver carp	x	bighead	(SB)

The last two hybrid forms were previously described by Vinogradov and Jerokhina (1964). Both these hybrids showed an increased survival at the larval stage and fingerlings of these hybrids appeared to be more viable. Despite some outward likeness with the silver carp, the hybrids differ from each other and parental forms in the structure of the filtering apparatus. In the structure and number of the gill rakers the hybrids are intermediate between the silver carp and the bighead. We have not come across any literature concerning the hybridization of the grass carp with the silver carp and the bighead. Therefore, it seems of interest to discuss here some results of the investigations of these hybrids.

Fertilization was carried out by a dry (Russian) method: the eggs taken from one female were divided into equal parts (30 ml) and fertilized with equal quantities of milt of different species. Thus, we obtained a parental form (control) and a hybrid progeny. Eggs were incubated in the glass Weiss apparatus equally filled. The percentage of fertilized eggs was determined by samples taken from 100 eggs at the stage of 16-32 blastomeres.

For a more precise comparative estimate of the survival of hybrids and initial forms in embryogenesis, a portion of the eggs at the beginning of the incubation was transferred to a flat glass vessel (500 eggs for each vessel). Dead (whitened) eggs were removed twice during incubation - by the end of gastrulation and at the stage of embryo formation (16 - 20 somites). As soon as hatching had been completed we calculated the output of normal larvae in the glass vessels. The majority of crossings was repeated twice (with different males and females). Unfortunately we could not obtain the bighead, so for reciprocal hybrids obtained from the crossing of the grass carp and silver carp with the bighead, had no second parental form for comparison.

First-time spawners were used for crossing which seems to have influenced the percentage of fertilized eggs. However with the exception of the hybrid SB in all other cases this percentage proved to be higher in hybrids. The output of normal larvae in the hybrid was almost the same as in the initial forms, and, as can be seen from the comparison of a progeny from one female, the hybrids sometimes possessed an obvious advantage (e.g. comparing GG with GB, and also GG with GS). The exceptions

Table IV

Survival of hybrids of the grass carp, silver carp and bighead in embryogenesis, June, 1965

Number of experiment	Cross		Percentage of fertilized eggs	Initial number of eggs	Percentage mortality	Percentage normal larvae 1/
1	Silver carp	SS	82.3	950	22.8	77.0 ± 1.38
	Hybrid	SG	84.8	850	33.6	single specimen
	Hybrid	GS	87.4	1,000	17.6	79.6 ± 1.27
	Grass carp	GG	80.0	1,050	40.0	60.0 ± 1.51
	Hybrid	GB	86.1	1,000	21.6	76.6 ± 1.34
2	Silver carp	SS	82.1	1,000	9.9	86.5 ± 1.09
	Hybrid	GS	87.7	1,050	14.7	78.5 ± 1.27
	Grass carp	GG	84.2	1,050	13.6	75.5 ± 1.33
	Hybrid	GB	94.7	550	8.5	86.9 ± 1.43
	Hybrid	SB	57.0	950	18.5	65.4 ± 1.54
	Hybrid	BS	92.3	1,000	11.3	87.9 ± 1.03
	Hybrid	BG	-	1,000	44.5	50.8 ± 1.58

1/ the number of hatched larvae was calculated in relation to initial number of eggs are the hybrids obtained by the crossing of the silver carp and bighead (SB) with the grass carp (GG). At the stage of moving embryo a severe mortality of eggs was noted in the hybrid SG; hatching was delayed and resulted in almost total mortality. The increased mortality of eggs observed during the development of the hybrid BG resulted in the output of larvae being as low as 50 percent. The causes of mortality are still not known; we had no reason to ascribe it to the poor quality of the milt.

Some of the crossings yielded larvae larger in size than in the initial forms (Table V).

Table V

The length of hatched larvae, June 1965

Cross		Length (mm)	Difference between the hybrids and initial form, p
Grass carp	GG	4.21 ± 0.018	
Hybrid	GS	4.80 ± 0.020	< 0.005
Hybrid	GB	4.50 ± 0.018	< 0.005
Silver carp	SS	4.64 ± 0.018	
Hybrid	SB	4.82 ± 0.019	<0.005

It is too soon to speak about heterosis in the hybrids obtained, but these experiments suggest that intergeneric crossings in these cases yield quite viable progeny.

The numbers of larvae of different hybrids obtained in 1965 were as follows:

hybrid	GB	10,000
hybrid	BG	3,000
hybrid	GS	2,000
hybrid	SB	3,000
hybrid	BS	300,000

In its outward appearance the hybrid GB differs from the grass carp as well as from the bighead. The number of scales in the lateral line of this hybrid is 60 to 67 (compare 40 to 43 scales in the grass carp and about 115 in the bighead). On the abdomen of the hybrid there is a keel typical of the bighead, while by its yellowish-green colouring the hybrid resembles the grass carp.

The difference in the food eaten by parental forms is determined by the structure of the filtering apparatus of these fishes (the grass carp chiefly feed on higher aquatic plants and the bighead on zooplankton). The grass carp possesses few short gill rakers, whereas the bighead has a dense row of long rakers [Fig. 1 (a) and (c)].[1/]

[1/] The structure of gill rakers in hybrid BS and in bighead is very similar.

The hybrid GB differs from the parental forms not only in the length and density of gill rakers, but also in their distribution on the gill arch. In the parental forms rows of rakers on internal and external edges of the gill arch run almost parallel, while in the hybrid they make an obtuse angle. The difference in the structure of gill rakers can be clearly seen from Table VI.

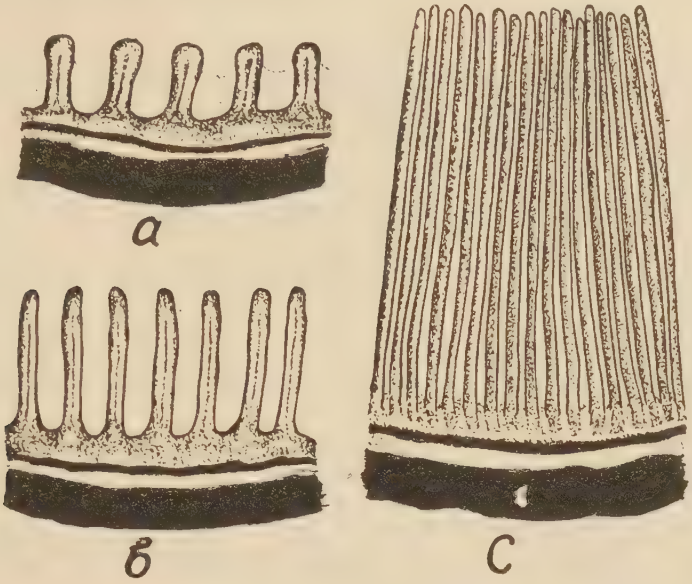


Fig. 1 Structure of gill rakers in:

(a) the grass carp
(b) hybrid GB, grass carp and bighead
(c) hybrid BS, bighead and silver carp

Taken from the middle part of the first gill arch, enlarged about 18 times

Table VI

Characteristics of gill rakers of the grass carp, hybrid GB, and hybrid BS, June 1965

Cross		Standard body length (cm)	Length of gill rakers (mm)	Width of gill rakers (mm)	Density of gill rakers per mm
Grass carp	GG	8.55	0.57	ca 0.07	3
Hybrid	GB	8.65	1.05	ca 0.10	4 - 5
Hybrid	BS[1]	8.25	3.15	ca 0.05	9 - 10

[1] The structure of gill rakers in hybrid BS and in bighead is very similar

Unfortunately we were not able to investigate the mode of feeding of this hybrid. The structure of the filtering apparatus indicates, we suppose, the ability of the hybrid to use more diverse food than the bighead. A comparative study of the growth rate of hybrids resulting from crossings of _C. idella_, _H. molitrix_ and _A. nobilis_ is planned.

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GENETICS AND SELECTION OF FISH AND ARTIFICIAL GYNOGENESIS OF THE CARP (CYPRINUS CARPIO)

by

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Abstract

Gynogenesis is a rare form of reproduction in which insemination is obligatory but the sperm nucleus does not take part in development, and the ovum nucleus, with the unreduced number of chromosomes, becomes the zygote nucleus. Therefore only maternal inherited properties develop. It occurs naturally in one form of crucian carp. This form consists of females only, which propogate by gynogenesis with the help of males of other fish species, giving only female progeny. The bisexual form is unable to propogate by gynogenesis.

Experiments are described using X-ray treatment of sperm to obtain diploid gynogenetic progeny of carp (Cyprinus carpio) and loach (Misgurnus fossilis) artificially. The cytological changes involved are discussed.

Artificially induced gynogenesis widens the boundary of genetic analysis. It also, thanks to the restitution of diploidy after the reduction division, permits a degree of homozygosis to be achieved in one generation which could otherwise only be achieved through long and very close inbreeding. Gynogenetic "clones" could be built up very quickly for use to gain the heterotic effect in further crossings.

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GENETIQUE ET SELECTION DE POISSONS - GYNOGENESE ARTIFICIELLE DE LA CARPE (CYPRINUS CARPIO)

Résumé

La gynogenèse est une forme de reproduction rare dans laquelle l'insémination est obligatoire mais où le noyau du spermatozoïde n'intervient pas dans le développement, tandis que le noyau ovulaire, sans réduction chromatique, devient le noyau du zygote. L'individu ne hérite donc que des caractères maternels. Ce type de reproduction a lieu naturellement chez une variété de carpe carassin. Cette variété ne comporte que des femelles, qui se reproduisent par gynogenèse à l'aide de mâles d'autres espèces de poissons et donnent uniquement une descendance femelle. La variété bisexuée est incapable de se reproduire par gynogenèse.

La communication décrit des expériences de traitement aux rayons X de sperme en vue d'obtenir artificiellement une descendance gynogénétique diploïde de carpe (Cyprinus carpio) et de loche (Misgurnus fossilis). Les modifications cytologiques survenues sont examinées.

La gynogenèse provoquée artificiellement élargit les frontières de l'analyse génétique. Elle permet également, grâce à la restitution de la diploïdie après réduction chromatique, d'obtenir en une seule génération un degré d'homozygotie qui ne pourrait être obtenu autrement qu'à la suite d'une longue et stricte endogamie. Des "clones" gynogénétiques pourraient être constitués très rapidement pour servir à obtenir, au cours de croisements ultérieurs, l'effet d'hétérosis.

GENETICA Y SELECCION DE PECES, GINOGENESIS ARTIFICIAL DE LA CARPA (CYPRINUS CARPIO)

Extracto

La ginogénesis es una forma rara de reproducción en la cual la inseminación es obligatoria pero el núcleo del esperma no toma parte en el desarrollo y el núcleo del huevo, con el número de cromosomas no reducido pasa a constituir el núcleo del cigoto. Por consiguiente, sólo se desarrollan propiedades heredadas maternas. Se verifica de modo natural en una forma de pez dorado o de la China. Esta forma está constituída por hembras solamente que se propagan por ginogénesis con ayuda de machos de otras especies íoticas y dan sólo descendencia femenina. La forma bisexual es incapaz de propagarse por ginogénesis.

Se describen los experimentos realizados utilizando tratamiento de esperma por rayos X para obtener artificialmente descendencia gimnogenética diploide de carpa (Cyprinus carpio) y locha de estanque (Misgurnus fossilis). Se discuten los cambios citológicos consiguientes.

La ginogénesis provocada artificialmente ensancha los límites del análisis genético. Asimismo, gracias a la restitución de la diploidia después de la reducción del número de cromosomas en la división, permite lograr un grado de homocigosis en una generación que, en otro caso, sólo se habría podido lograr mediante prolongados y muy próximos cruzamientos por consanguinidad. Se pudieron constituir muy rápidamente "clones" ginogenéticos con el fin de utilizarlos para alcanzar el efecto heterótico en posteriores cruzamientos.

1 INTRODUCTION

Gynogenesis is a special and rare form of reproduction which combines features of usual bisexual reproduction and parthenogenesis. In gynogenesis insemination is obligatory and the nucleus of the sperm penetrates into the ova. But then the sperm nucleus does not take part in the development, and the ovum nucleus with the unreduced number of chromosomes becomes the nucleus of the zygote. Therefore only maternal inherited properties develop. Thus the basis of this peculiar form of reproduction consists of two different phenomena, i.e. the inactivation of the sperm nucleus, and the retention of the number of maternal chromosomes unreduced. In natural gynogenesis both phenomena are combined and are part of the life cycle of unisexual forms. These include the unisexual form of the crucian carp (Carassius auratus gibelio) which is common in the U.S.S.R. and important in pond pisciculture.

2 FORMS OF CRUCIAN CARP

We have found that there are two forms of the crucian carp which look alike but are quite different in their method of reproduction. Females of the unisexual form comprising the bulk of population in the U.S.S.R. propagate by gynogenesis with the help of males of other species of fish, giving a progeny of female crucian carp only. Females of the bisexual form are unable to propagate by natural gynogenesis. When crossed with males of other species they give hybrids and crossed with male crucian carp they give birth to a bisexual progeny. The data obtained during our investigations have been published in a number of articles by Golovinskaia and Romashov (1947; 1954; 1965), and Golovinskaia, Romashov and Cherfas (1965).

3 EXPERIMENTS TO INDUCE GYNOGENESIS

The natural occurrence of gynogenesis in crucian carp prompted experiments to obtain a diploid gynogenetic progeny of other species of cultivated fish. This was connected with a number of problems important to breeding, and above all with control of sexual composition and design of special methods of selection.

The very first experiments on the carp, loach (Misgurnus fossilis) and some species of sturgeon (Acipenseridae) have shown that the gynogenetic inactivation of sperm can be achieved in a rather simple way. In our experiments we treated the sperm with heavy doses of X-rays. This method is described by Romashov et al. (1960; 1963), and Golovinskaia, Romashov and Cherfas (1963).

In experiments on the carp we have succeeded in excluding the father genome by applying the method of "signal" genes and hybridization. It is well known that crossing a female of the scattered carp (recessive gene - ss), with a male of the scaly carp gives scaly carp progeny if the male is homozygous (SS). In an experiment in artificial gynogenesis with such a set of spawners, a scattered carp progeny instead of a scaly one was produced. This result was exactly the one expected. In the control with the normal sperm of the same male all the progeny was scaly. The insemination of eggs of the carp with the sperm of the crucian (Carassius carassius) gave similar results. The experiment in artificial gynogenesis gave a carp progeny and the control brought about hybrids.

However, in all these experiments the bulk of gynogenetic progenies consisted of haploid embryos which died soon after extrusion. The yield of diploid gynogenetic embryos was extremely low, i.e. from 0.1 - 0.3 to 1.0 - 3.0 percent of the number of spermatized eggs. This is connected first of all with the fact that in the case of normal sperm, the re-establishment of the diploidy of the reduction complex of female chromosomes occurs extremely rarely. Besides this, the mortality rate of the young is very high. As a result of this we have managed to conserve and rear only a few specimens of gynogenetic origin. At present there are only eight carp at the age of four years in the experimental stock of the Jakotj Institute.

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It was obvious that the study of diploidization and working out methods for its stimulation was necessary to make the method of artificial gynogenesis applicable to selection. Experiments on this were made on the loach, a very suitable fish for the purpose.

The investigations carried out by Romashov and Belyaeva have shown that by temperature treatment of eggs soon after insemination, during the period of the anaphase of the second meiotic division, it is possible to considerably increase the number of diploid gynogenetic embryos, bringing it in case of individual females up to 50-60 percent. Under these conditions the following changes take place. The separation of the second polar body is retarded as it becomes absorbed again in the plasma of the oocyte, the haploid chromosomes join those remaining in the oocyte, and thus the diploidy of the ovum nucleus returns to normal and becomes the nucleus of the zygote.

In the natural gynogenesis of unisexual crucian carp the first meiotic division is upset. According to the investigations made by Cherfas (1965) it does not terminate in the separation of the first polar body, and in this case the conjugation of chromosomes does not take place, which is very important. The second meiotic division (the only one in this case) develops as the usual mitosis, and the mature oocyte, as well as the polar body (also the only one) separated after ovulation, retains the initial number of maternal chromosomes. According to the latest data obtained by Cherfas this number of chromosomes has proved to be triploid.

In the artificial gynogenesis of the loach the whole development is quite different, and that determines the genetic after-effects depending on the moment of the restitution of diploidy.

If diploidization had been connected with the first meiotic division, the maternal genotype would have been repeated and segregation would have been excluded. If diploidization takes place later, and is connected with the second meiotic division, the segregation of the progeny is inevitable.

Our experiments on the carp have clearly proved the segregation of the gynogenetic progeny by mothers which were heterozygous for certain. It proves that the cytological basis for diploidization in both the carp and the loach are the same. In both cases the reestablishment of the diploidy is conditioned by the exclusion of the second meiotic division.

The data on the scaly covering characteristics of females of the carp and their gynogenetic progeny are given in Table 1. The scheme of the hereditary characteristics of the scaly covering of the four main genotypes of the cultured carp are also given. These are known to be determined by a combination of two pairs of alleles. Their genetic formulae are as follows:

SSnn and Ssnn - scaly
ssnn - scattered
SSNn and SsNn - linear
ss Nn - leather
SSNN, SsNN, ssNN - unviable

In the gynogenetic progeny of the scattered females (ssnn homozygotes) only scattered segregants were found, as was to be expected.

Table I

Segregation in the scaly covering characteristics of the carp in artificial gynogenesis

Time of investigation	Females	The number of specimens in progeny	
		number of specimens	segregants
1958	scattered	4	scattered
	ssnn		
1959	-"-	1	-"-
1959	-"-	28	-"-
1959	-"-	6	-"-
1958	scaly	8	scaly
	Ssnn	1	scattered
1959	-"-	3	scaly
1961	scaly /3/	19	scaly
	Ssnn	10	scattered
1958	first linear	3	linear
	SsNn		
1961	second linear	8	linear
	SsNn	2	leather
1962	-"-	2	linear
		5	leather

The progeny of the scaly females (all Ssnn heterozygotes) contained both scaly and scattered segregants. This fully agrees with the data obtained by usual genetic analysis, i.e. if in normal conditions Sn and sn gametes are formed, the restitution of diploidy brings about SSnn and ssnn gynogenetic zygotes. But as to the progeny of the linear females (both females - SsNn) the result of segregation was quite different. Here again scaly and scattered progenies were expected because NN specimens are unviable. The SN, sN, Sn and sn gametes formed in normal conditions should bring about SSNN and ssNN gynogenetic zygotes, which give unviable embryos and viable SSnn and ssnn zygotes. The result was exactly opposite: neither scaly nor scattered segregants were seen, but linear and leather ones appeared. Despite the negligible number of descendants, this result cannot be regarded as accidental as it was obtained from two females at different times. In addition the second linear female which gave two gynogenetic progenies was subjected to another progeny test in 1962. After the fecundation of its eggs with the normal sperm of two different males, i.e. scaly and linear, in the progeny all the expected categories having the co-relation determined by the genotype of the fathers were obtained. One could also observe the dying of NN homozygotes during the extrusion and soon after it (see Table II).

Table II

The progeny of a linear female (SsNn) in case of normal fecundation and artificial gynogenesis

Experiment	Percentage of fecundated eggs				State of embryos during hatching		Scaly covering of progeny in percent			
	died before hatching	died during hatching	hatched							
			monsters that died soon	normal	percent monstrous	percent normal	scaly Sn	linear SN	scattered sn	leather sN
scaly Ssnn								expectancy		
normal fecundation	28.5	0.5	6.0	65.0	8.5	92.5	37.5	37.5	12.5	12.5
								obtained		
							42	36	11	11
linear SsNn								expectancy		
	24.0	7.0	18.0	51.0	26.1	73.9	33	67	-	-
								obtained		
normal fecundation							32	68	-	-
linear the same inactivated								expectancy		
sperm	31.0	42.0	26.0	1.0	96.3	3.7	50	-	50	-
								obtained		
gynogenesis								29	-	71

It is evident that gynogenetic linears and leathers must have the Nn structure. The question is how this structure could appear in the gynogenetic zygote. In our opinion (Golovinskaia and Romashov, 1965) the most probable explanation of this is as follows. The N and n alleles do not separate in the first, but in the second meiotic division, which is due to crossing-over with an exchange of parts of non-sister chromatids affecting the N and n loci. In this case both alleles become contained in each bivalent member and in the first meiotic division move to the poles together, parting only in the second meiotic division. If the second division is full, as in the case with normal sperm,the exchange that takes place remains unnoticed, due to the absence of the second gene-marker in the given pair of chromosomes because there are found the same two kinds of gametes carrying N genes or n genes respectively. If in the second meiotic division diploidy is re-established Nn zygotes appear. In this case we have to assume a very high frequency of such an exchange. Otherwise in the gynogenetic progeny we should have found scaly and scattered segregants which appeared without crossing-over. It is easy to calculate that in case of such crossing-over in half the meioses that take place, scaly and scattered segregants would have to comprise one third of the viable gynogenetic progeny of the linear females.

All the above considerations need further experimental studies, which we hope to carry out by increasing the yield of diploid gynogenetic progeny as was done in the case of the loach.

4 PROSPECTS FOR ARTIFICIAL GYNOGENESIS

The data obtained are sufficient to show what prospects the method of artificial gynogenesis has. Firstly it widens the boundaries of genetic analysis, coming in this respect closer to the "tetrad" analysis of haploid organisms (for instance in the case of the neurospora) where one can trace the destiny of each of the four chromatids. Secondly, artificial gynogenesis, thanks to the restitution of diploidy after the reduction division, allows one to achieve in one generation a degree of homozygosis which can only be obtained otherwise through long and very close inbreeding. This gives the possibility of creating quickly various gynogenetic "clones" which can be used to gain the heterotic effect in further crossings.

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THE CULTURE OF CARP AND TILAPIA HYBRIDS IN UGANDA

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Abstract

Because of the high rates of reproduction of *Tilapia* spp., their culture in Uganda failed to produce big fish preferred by the consumers.

In attempts to find more suitable fish for pond culture, the common carp (*Cyprinus carpio*) and mono-sex hybrids of male *Tilapia mossambica* and female *T. nilotica*, were tried. Evaluation of the results obtained has shown that there is no significant difference in the growth rates of these fishes.

Under conditions in Uganda the production of the tilapia hybrid fry is easier than that of carp fry, especially because efficient ways of controlling frogs, which are heavy predators of carp fry, are not known.

Best yields were obtained by mixed culture of tilapia hybrids and carp. The carp has so far failed to establish itself in natural bodies of water and has not affected native species as anticipated.

L'ELEVAGE D'HYBRIDES DE CARPE ET DE TILAPIA EN OUGANDA

Résumé

En raison de leur taux élevé de reproduction, l'élevage de Tilapia spp. en Ouganda n'a pas permis d'obtenir les gros poissons vers lesquels vont les préférences des consommateurs.

Pour essayer de trouver des poissons correspondant mieux aux besoins, on a effectué des essais avec des carpes communes (Cyprinus carpio) et des hybrides mâles de Tilapia mossambica et femelles de T. nilotica. L'expérience a montré qu'il n'y avait aucune différence sensible dans les taux de croissance de ces poissons.

Dans les conditions régnant en Ouganda, il est plus facile de produire des alevins de tilapia hybrides des alevins de carpes, d'autant plus que l'on ne connaît pas de moyens efficaces pour lutter contre les grenouilles qui exercent des ravages parmi les alevins de carpes.

Les meilleurs résultats ont été obtenus en élevant en association des hybrides de tilapia et des carpes. Jusqu'à présent la carpe n'a pas réussi à s'établir dans les plans d'eau naturels et n'a pas affecté les espèces indigènes comme on le prévoyait.

EL CULTIVO DE HIBRIDOS DE CARPA Y TILAPIA EN UGANDA

Extracto

A causa de la elevada tasa de reproducción de Tilapia spp., su cultivo en Uganda no llegó a producir el pescado de tamaño grande preferido por los consumidores.

En el intento de encontrar peces más adecuados para la piscicultura, se ensayaron la carpa común (Cyprinus carpio) y los híbridos monosexuales de machos de Tilapia mossambica y hembra de T. nilotica. La evaluación de los resultados obtenidos ha demostrado que no existe una diferencia notable en las tasas de crecimiento de estos peces.

En las condiciones que se dan en Uganda la producción de alevines de híbridos de tilapia es más fácil que la de alevines de carpa, a causa, principalmente, de que todavía no se conocen medios eficaces de luchar contra las ranas que son grandes devoradoras de alevines de carpa.

Los mejores rendimientos se obtuvieron mediante el cultivo mixto de híbridos de tilapia y carpa. Hasta el momento, no ha logrado establecerse en masas naturales de agua y no ha perjudicado a las especies indígenas como se temía.

1 INTRODUCTION

Fish farming was first started in Uganda in 1953, and the species used in the ponds at this time were Tilapia zillii, T. nilotica and T. leucosticta. The practice soon proved popular and today forms a highly important aspect of fish production in areas remote from the main lakes of the country. The latest estimate showed that there were 10,000 ponds in existence in 1963, all having been built since fish farming first started a decade earlier.

When populations of tilapia species are allowed to grow unchecked in ponds of limited size, the high rate of reproduction of the species leads to a rapid increase in numbers. Under these conditions individual fish attain maturity at a far smaller size than they would under natural conditions (FAO/UN, 1961). Owing to this, the original technique employed in farming tilapia was one of thinning the population during growth of the fish to prevent stunting, and to produce large fish of between 200 g and 500 g. This method was suited to the marketing of fish in Uganda where large fish are preferred. For many reasons, but due mainly to the difficulty of employing the technique in general fish farm management, this method was not successful, producing yields of only 200 kg to 300 kg per hectare made up of numerous small fish.

Alternative species, having a high rate of growth and a low reproductive capacity, were sought by the Fisheries Department. Mirror carp (variety of common carp, Cyprinus carpio) were considered to be suitable as they combined both these properties, and they were therefore introduced from Israel in 1957. Mono-sex cultures of Tilapia species obtained by hybridization were commenced in 1962 as a further experiment in the control of population in ponds.

This paper is a preliminary summary of these two experiments and an evaluation of the results.

2 ENVIRONMENT AND PRODUCTIVITY

A classification of fish ponds in Uganda, and estimates of their potential productivity were made by Wurtz (FAO/UN, 1961). In this study the ponds were divided into two groups:

(i) those established on a clay or sand bottom, and having a pH of 6.5 - 7.5,

(ii) those established on a peaty substrate on the edge of papyrus swamps, and having a pH of 5.0 - 6.5.

Most of the experimental work was carried out at Kajansi Fish Farm where the ponds belong to the first group described by Wurtz, and also have a high silt content. The temperature of the pond water at Kajansi varies between 18°C and 28°C. The potential yield of these ponds was calculated by Wurtz using various methods, and was found to be 500 kg - 766 kg per hectare per annum. The actual yields obtained from ponds containing tilapia were between 200 kg and 300 kg/hectare/annum. The reason for this difference was that Wurtz considered tilapia to be bad converters of food and believed carp would do better; they have in fact not come up to his expectations in this respect at Kajansi, but results have not been far short of Wurtz's predicted yield in Kigezi district.

3 CARP CULTURE

3.1 Introduction of carp

The introduction of carp in Uganda was first proposed in 1951, but stocking did not occur until 1957. Objections raised against the introduction of carp included the possibility that they would compete with endemic species for food and breeding grounds in the event of their getting access to the major lakes, and that it may also ruin sport fishing for trout in the mountain streams. The history of carp as a good pond fish in Europe and the Far East, however, favoured its introduction for stocking purposes (Rhodes, 1961). After six years of observations made since the original introduction neither the fears nor the hopes expressed have fully materialized.

3.2 Reproduction

The first spawning of carp took place in 1959 from the stock which was introduced from Israel. The average weight of the fish on spawning was 2,000 g and the number of fry produced by one fish was 3,913. In later spawnings the number of fry produced per fish was much lower, ranging from 200 to 500. Predation by water insects such as Notonectidae, and frogs, mainly Xenopus sp. was found to be responsible for the low survival rate of fry from the later spawnings. By eliminating the insects from the ponds by treatment with 1 ppm of three percent B.H.C., fry survival was increased to 2,000 - 5,000 fry per female. No efficient method has yet been found for controlling the frogs, but some improvement in survival has been noted recently in ponds protected by special fencing.

In order to maintain the brood stock in good condition, a factor necessary for the females to develop ovaries, it was found that the ponds must be stocked at low densities, not exceeding 200 kg per hectare. This stocking density is very low when compared with the current practice in Israel of stocking between 700 kg and 1,000 kg per hectare and maybe due to the small area of the individual ponds in Uganda.

3.3 Rate of growth and yield

Under conditions where food was not added to ponds stocked at 600 kg to 2,000 kg per hectare the daily gain in weight per fish was between 0.5 g and 3.0 g. The results of experiments in which food was added to the ponds carried out at Kajansi by Simpson (1962) showed a daily gain in weight of 1.6 g per fish, with a food conversion of 1:5. This conversion figure was obtained by dividing the weight of food added to the ponds by the weight of fish cropped, and did not take into account that part of the weight of cropped fish derived from food occurring naturally in the ponds. The figures used in the calculation of the conversion figure were obtained at a time when the growth of the fish was recorded at densities between 200 kg and 250 kg per hectare. The addition of fertilizers to the pond did not change the resulting yield during the experiments. Similar results were obtained by the author in experiments carried out between 1962 and 1964.

The poor response in growth of carp in ponds to which food and fertilizers were added was probably due to the high turbidity of the Kajansi carp ponds, reducing light penetration. This in turn reduces the production of natural food in the ponds which is essential for the full utilization of added food by the carp. In ponds with sandy bottoms as are found in Serere,Teso District, in Kisubi Buganda Kingdom and in certain areas of Bugisu District where the water is relatively clear and light penetration high, the yields were higher, reaching about 1,000 kg per hectare per annum.

3.4 Growth and pH

The best results were obtained in ponds where the pH was between 7.5 and 8.5. The carp did not grow rapidly in ponds with a pH of 6.5 or less. However, in the cooler, upland areas of Kigezi District, good growth and yields of up to 700 to 1,000 kg per hectare were obtained in ponds with a pH of 6.0 which had been built on peaty/loamy bottoms on the edge of papyrus swamps and in which natural food was abundant. The pH may not affect the growth of carp but may influence the growth of food organisms.

3.5 Carp in natural bodies of water and dams

During the course of the experiments carp fingerlings were stocked in several dams and minor lakes. Growth of carp was very good under these natural conditions, and some of the fish attained a weight of three kg after the first year.

Reproduction was observed in one of the stocked lakes, Lake Mulehe of over 400 ha. No legal restriction on commercial fishing was effected on this lake as was done on other small bodies of water in Uganda when stocking with other species was carried out. In consequence a commercial fishery soon developed for carp and the fry production has so far not been sufficient to maintain the stock. Further restocking was found necessary to maintain the carp fishery in this lake.

The carp could not escape predation in dams where Nile perch were established, and disappeared in a short time.

4 MONO-SEX CULTURE OF TILAPIA SPECIES THROUGH HYBRIDIZATION

4.1 Hybridization

Out of the many crosses successfully tried at Kajansi the only cross to produce 100 percent males in the F1 generation was the one between males of Tilapia mossambica (from Zanzibar)and females of T. nilotica (from Lake Albert) (Pruginin and Kanyike, 1965).

4.2 Fry production

The results of the study of the above cross showed that male Tilapia mossambica and female T. nilotica must be stocked in the ponds in the ratio of two males to three females. Special attention was paid to prevent entry of wild Tilapia to the ponds from the natural water supply system at Kajansi, by using fine gravel beds through which water was screened. The optimum rate of stocking was found to be between 25 and 30 females per 1,000 m^2.

4.3 Growth and rates of stocking

In order to compare growth rates, hybrids resulting from the above cross were stocked in the same pond with Tilapia nilotica. The results of this experiment showed that after six months the gain in weight of the hybrids was 20 percent higher than that of the T. nilotica. When the hybrids were stocked separately the difference in weight in favour of the hybrids was even greater. Experiments were carried out using hybrids at densities of 1,000 to 2,500 fry per hectare. A density of 1,500 hybrids per hectare yielded 800 kg per hectare per annum.

Tilapia mossambica proved to be of little value when cultured separately, as the species started breeding at a size of 6 cm to 7 cm with the weight of individual fish not exceeding 100 g after one year's growth.

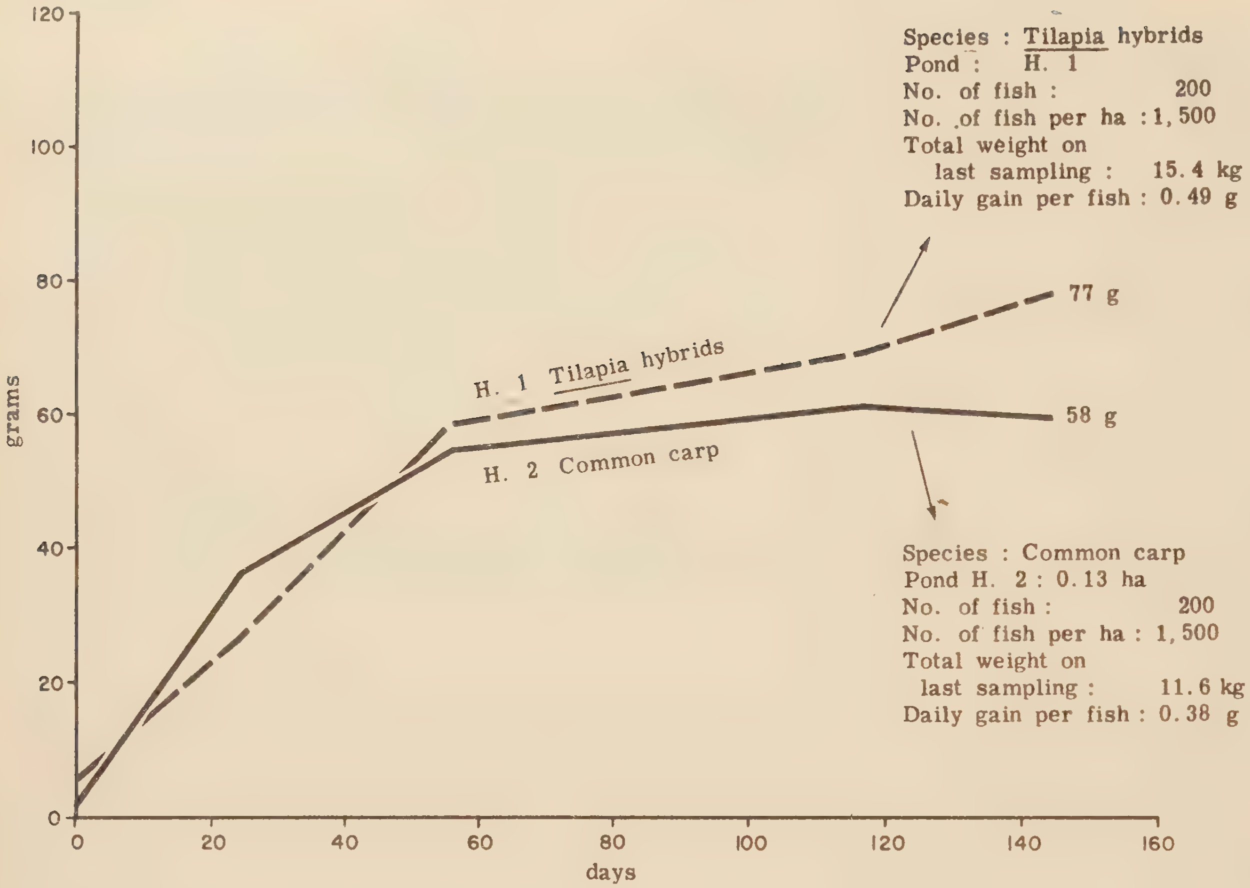
4.4 Nursing

It was observed that when hybrids were stocked at a density of 8,000 per hectare the growth rate up to 50 g did not differ from that of fry kept at lowered densities. When nursed under such high density conditions, however, the fry should be transferred to rearing ponds at densities of 1,000 to 1,500 fry per hectare when they attain a weight of 50 g if normal growth is to continue. The daily gain of hybrids in rearing ponds was 1.5 to 3.0 g per fish, and individual fish reached a weight of 200 g to 450 g after a period of 100 - 150 days.

Experiments to determine the optimum density for nursery and rearing ponds are still in progress.

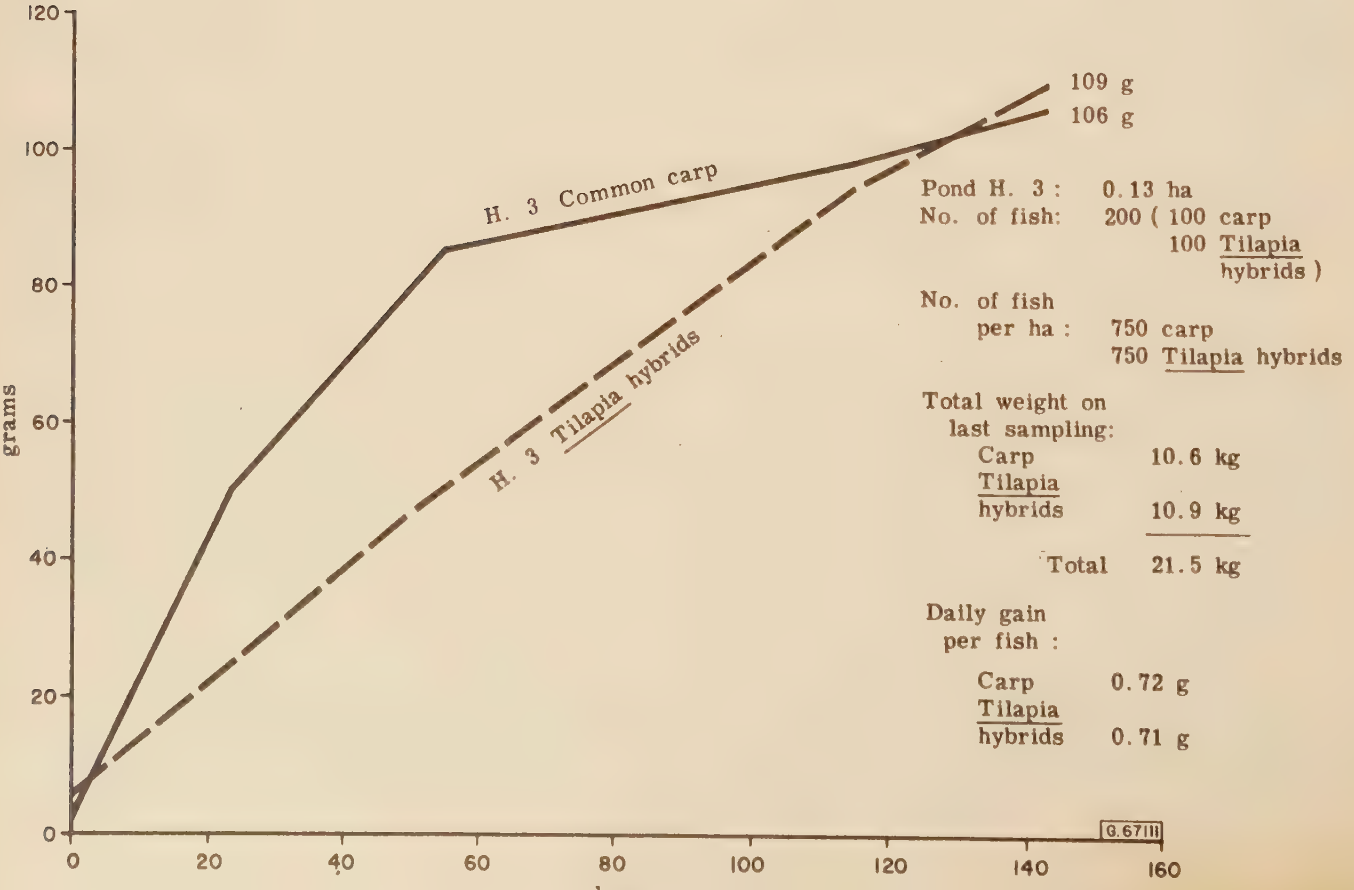
4.5 Fertility

The hybrids were tested for fertility by back-crossing with female Tilapia nilotica, and were found to be fertile. The offspring from the back-cross proved to have the normal sex ratio.



Species : *Tilapia* hybrids
Pond : H. 1
No. of fish : 200
No. of fish per ha : 1,500
Total weight on
last sampling : 15.4 kg
Daily gain per fish : 0.49 g

Species : Common carp
Pond H. 2 : 0.13 ha
No. of fish : 200
No. of fish per ha : 1,500
Total weight on
last sampling : 11.6 kg
Daily gain per fish : 0.38 g



Pond H. 3 : 0.13 ha
No. of fish: 200 (100 carp
100 *Tilapia* hybrids)
No. of fish
per ha : 750 carp
750 *Tilapia* hybrids

Total weight on
last sampling:

Carp	10.6 kg
Tilapia hybrids	10.9 kg
Total	21.5 kg

Daily gain
per fish :

Carp	0.72 g
Tilapia hybrids	0.71 g

The hybrids attain sexual maturity at five to six months. This is the maximum length of time that the breeding ponds should be used, otherwise back-crossing will occur between the hybrids and the T. nilotica of the original breeding stock.

The hybrids are easy to identify since they have characteristics which are intermediate between the parents and differ in shape from the male Tilapia mossambica, so there should be no mistakes in selecting fish for breeding.

4.6 Multiple stocking with carp

Carp and hybrids were stocked at various ratios at densities of 1,200 to 2,800 per hectare. In most cases the total yields of the multiple stocked ponds were considerably higher than those of ponds stocked separately with carp and hybrids (Fig. 1 and 2).

Experiments to determine the response of hybrids to food added to the ponds are being carried out at present.

5 DISCUSSION AND CONCLUSIONS

In the Kajansi ponds, which are not typical of many in Uganda, carp under non-feeding conditions yielded low crops of 200 to 300 kg per hectare, which was similar to the yields of tilapia ponds. When food was added to the carp ponds the additional yield was not profitable. Tilapia hybrids in the same environment produced higher yields of up to 700 kg per hectare per annum.

In ponds with sandy bottoms the yields of both carp and tilapia hybrids were 800 kg to 1,300 kg per hectare per annum, with no significant advantage to either species. The production of tilapia hybrids is less expensive than that of carp fry, as more fry are produced per spawning. It appears from experience in fry centres in various parts of Uganda that the production of tilapia hybrids is less complicated than that of carp fry.

It may be concluded after six years of experiments on carp culture that carp has not fulfilled the expectation of becoming an important fish in fish farming in Uganda. Its value is limited as a secondary fish in tilapia ponds in most areas of the country except for Kigezi District where the lower temperatures are a limiting factor for tilapia growth.

It may also be concluded that carp could not become a pest by damaging the environment of natural bodies of water. Carp culture is more important in areas of high altitude where temperatures are too low for good growth of Tilapia spp.

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IV/E-13

QUELQUES EXPERIENCES AVEC LE FRAI ARTIFICIEL DE LA CARPE

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Résumé

On présente dans ce rapport les résultats de l'élevage des alevins de carpe obtenus suite à la pratique de la fécondation artificielle de carpes femelles au cours des 5 années d'expérimentation. L'ovulation des oeufs a été provoquée par des injections d'hypophyse. La suppression de la viscosité des oeufs a été obtenue par la méthode de Woynarovich. L'incubation s'est faite dans des appareils de Zoug. On discute aussi de l'élevage des alevins jusqu'à 5 à 7 jours sur du tissu de toile métallique ainsi que de leur élevage ultérieur dans des conditions naturelles.

EXPERIMENTS WITH CARP FRY OBTAINED BY ARTIFICIAL FERTILIZATION

Summary

This paper reports the results of five years' experiments in raising fry from artificially fertilized common carp. Ovulation was induced by pituitary gland injections. The Woynarovich method was used to prevent the eggs from sticking together. The eggs were incubated in glass jars (Zuger apparatus). Details are given on the raising of fry on metal gauze till 5 to 7 days of age, and afterwards under natural conditions.

EXPERIENCIAS SOBRE EL DESOVE ARTIFICIAL DE LA CARPA

Extracto

Se exponen en este informe los resultados de la cría de alevines de carpa obtenidos por la fecundación artificial de carpas hembras en el curso de cinco años de experimentación. La ovulación de los huevos se provocó con inyecciones de células hipofisarias. Se suprimió la viscosidad del huevo mediante el método de Woyranovitch. La incubación se efectuó en los aparatos de Zoug. Se explica también la cría de alevines de 5 a 7 días sobre tela metálica, así como su cría ulterior en condiciones naturales.

1 INTRODUCTION

La production intensive de carpes en étangs demande aujourd'hui une grande quantité de carpillons de bonne qualité, ce que les méthodes utilisées jusqu'à présent ne peuvent pas toujours assurer en quantités suffisantes.

La production contemporaine de la feuille se fonde sur la fraie artificielle de la carpe, qui contribuera considérablement à la production de la feuille de bonne qualité ainsi qu'en ce qui concerne la quantité nécessaire à un empoissonnement suffisamment dense.

Les avantages de la fraie artificielle de la carpe consistent en l'obtention plus rapide de la fraie des carpes reproductrices, ainsi qu'en élevage plus rapide de la feuille en une plus grande fertilité et en une meilleure sélection du matériel pour la reproduction.

L'élevage de la carpe par la fraie artificielle a commencé récemment. Plusieurs auteurs allemands, hongrois et russes comme par exemple E. Probst, W. Steffens, E. Woynarovich, Gerbilski et certains autres se sont occupés de ce problème et chez nous, en Yougoslavie, les premiers qui ont reçu de bons résultats déjà en 1949 étaient P. Herzog et O. Rogovski, et récemment aussi D. Cehović, D. Janković, M. Ristić, B. Jovanović et D. Denadić. Depuis 1961, l'Institut pour la Pisciculture en eau douce à Zagreb fait des examens en ce domaine.

2 LES EXAMENS EFFECTUES PAR NOTRE INSTITUT

Les examens ont été effectués dans quelques uns de nos grands étangs qui sont pourvus de l'équipement nécessaire et on a fait aussi à cette fin des constructions requises.

Nous allons donner ici un bref exposé de notre travail et des résultats obtenus depuis 1961 jusqu'à 1965.

Les carpes reproductrices que nous avons prises pour nos examens se trouvent pendant leur maturation dans les bassins en terre, séparées selon les sexes et nourries avec la nourriture abondante en protéines. Dès que les reproducteurs arrivent à la maturité, on les prend en traitement. Ces essais ont été effectués à l'époque de la fraie de la carpe dans nos étangs, c'est-à-dire au mois de mai et dans la première moitié du mois de juin.

Le nombre total des reproducteurs traités s'est élevé à 351, dont 234 carpes mâles et 117 carpes femelles, âgées de 3 à 12 ans et leur poids individuel s'élevait de 4 à 14 kilogrammes. La sélection des reproducteurs se fait d'après la forme, la disposition des écailles et l'état de santé.

3 INJECTION DES HYPOPHYSES

Pour stimuler la maturation et l'ovulation des oeufs, on injecte les hypophyses et les hormones.

On a injecté ainsi 500-1000 unités internationales de Choriogonadine par carpe reproductrice et les 10 essais qui ont été faits ont eu des résultats négatifs. C'est pourquoi on a éliminé la Choriogonadine à l'occasion des essais ultérieurs.

Les hypophyses injectées ont été enlevées aux carpes femelles et aux carpes mâles arrivées à la maturité quelques heures seulement avant d'être injectés. On les a laissées un certain temps dans l'acétone et ensuite on les a préparées pour l'injection.

L'injection des hypophyses appliquée aux carpes reproductrices a été effectuée à une température de l'eau de 18°C environ et par beau temps, ce qui est très important. Les injections ont été données intramusculairement.

On a injecté 117 carpes femelles.

Dans la première année du travail, on a injecté aussi des hypophyses aux carpes mâles, mais puisqu'ils donnaient une quantité suffisante de laitance, les injections des hypophyses n'étaient pas nécessaires.

On n'employait pas toujours les mêmes doses des hypophyses. Dans les premières années du travail, une dose contenait 1, 2 et même 3 hypophyses. Ces doses ont été injectées une fois, deux fois ou bien trois fois par jour, dans les intervalles de 24 heures. Ainsi certaines carpes femelles ont reçu même 9 hypophyses dans l'espace de trois jours. En 1965, les doses étaient plus grandes encore: 1 hypophyse par 1 kg du poids de la carpe reproducteur, une fois par jour. La carpe femelle a reçu ainsi 9 hypophyses d'une seule fois.

Au début de notre travail, on a injecté aux carpes femelles les hypophyses des carpes femelles. Comme les effets des hypophyses des carpes femelles et des carpes mâles étaient les mêmes, on a injecté dans le travail ultérieur les hypophyses des carpes mâles aux carpes femelles, parce que nous avons eu toujours à la disposition la quantité nécessaire de carpes mâles - reproducteurs.

Après les injections, les reproducteurs ont été séparés selon le sexe et tenus dans les bassins en ciment à cause d'une manipulation plus convenable et de la possibilité de l'observation. Mais ils n'y devaient pas rester trop longtemps, à cause des dommages corporels et des plaies, ce qui avait un effet nuisible sur leur état physiologique.

C'est pourquoi, lorsque les circonstances le permettaient, nous avons tenu les reproducteurs injectés avec des hypophyses dans des bassins en terre, c'est-à-dire dans les conditions les plus naturelles possibles, avec les carpes mâles arrivées à la maturité, dans le but d'une maturation plus rapide des carpes reproducteurs. On a obtenu un taux plus grand de l'ovulation.

On a obtenu l'ovulation des oeufs ches 48 pour cent des femelles traitées. Selon les années, ce taux a varié de 28 à 83 pour cent.

L'ovulation des oeufs de la carpe a commencé 16 à 20 heures après l'injection des hypophyses.

A l'occasion de nos essais l'ovulation chez la majorité des femelles a commencé après l'application de 3 hypophyses : en 1962 chez 75 pour cent des femelles.

Chez 25 % des femelles qui frayaient, on est arrivé à l'ovulation complète, tandis que chez les autres femelles, on n'est arrivé que jusqu'à l'ovulation partielle et la quantité des oeufs était relativement plus petite.

Après avoir été déposées dans les viviers, c'est-à-dire quand elles se trouvaient de nouveau dans les conditions naturelles, les femelles à ovulation partielle continuaient de frayer, mais certainesd'entre elles n'ont pas survécu.

A l'époque de la fraie de la carpe, dans nos conditions climatiques, la température des eaux n'étant pas toujours la même, a un effet nuisible sur le processus de la fraie artificielle de la carpe.

4 LE TRAITEMENT DES OEUFS, FECONDATION, DEVELOPPEMENT DES ALEVINS, ECLOSION

Les oeufs ont été fécondés par le sperme d'un ou de plusieurs mâles. La fécondation des oeufs de bonne qualité a toujours eu de bons résultats et s'est élevée à 80 jusqu'à 90 pour cent. Chez les oeufs trop mûrs, on n'est pas arrivé jusqu'à la fécondation.

L'incubation des oeufs s'est développée en bocaux de verre (appareils de Zuger) où les oeufs étaient constamment mais doucement remués par le courant d'eau. Pour appliquer ce procédé il fallait préalablement écarter la viscosité des oeufs. Dans la première année du travail, la viscosité des oeufs a été écartée en les remuant et en les rinçant imtensivement avec la solution d'amidon. Cette méthode n'étant pas convenable à cause du collage des oeufs et par conséquent de leur dépérissement, on a décidé d'appliquer la méthode de Woynarevich. Cette méthode consiste en lavage et en rinçage des oeufs avec des solutions de carbamide (CO NH_2 p.a) et de sel de cuisine (NaCl p.a.) à des concentrations diverses; elle a donné des résultats satisfaisants. Ce traitement des oeufs est assez long et dure 5 heures.

Le développement embryonnaire des oeufs dure de 2,5 à 7,5 jours (52,5 jusqu'à 100,0 jours/degrés). Cette grande prolongation de l'incubation jusqu'à 7,5 jours a été conditionnée par la température basse des eaux.

Les pertes des oeufs pendant l'incubation étaient différentes, de 20 à 50 %. La raison de ces pertes n'était pas seulement la température et l'eau troublée, mais aussi la qualité des oeufs (le degré de la maturité des oeufs et l'âge des reproducteurs). Chez tous les reproducteurs et dans tous les étangs, les pertes n'étaient pas les mêmes.

La quantité d'oxygène dans l'eau était pendant l'incubation toujours suffisante pour le développement des oeufs et s'élevait à 12-13 mg/l, tandis que la valeur de pH variait de 7,0 à 8,8.

Pour protéger les oeufs de l'attaque de saprolegnia, on a baigné les oeufs dans le vert de malachite, d'une concentration de 0,01 pour cent pendant 15-30 minutes.

A cause des mesures prises, la circulation d'eau dans les appareils de Zuger et l'incubation brève des oeufs de la carpe, l'attaque de saprolegnia ne présentait pas des pertes significatives.

L'éclosion s'est effectuée dans des paniers en osier ou sur toile métallique à claire-voie dans des bassins en ciment.

L'intensité de l'éclosion et le développement des alevins âgés de 5 à 7 jours, à une température d'eau convenable, se sont déroulés presque sans pertes. Les alevins sont, après éclosion, très sensibles à la température, c'est pourquoi en 1962, après un abaissement rapide de la température d'eau (dans un espace de temps de 2 jours, la température d'eau s'abaissait de 11°C) les alevins périssaient en masse. Les alevins sont plus sensibles à la température que les oeufs de la carpe.

5 ELEVAGE ET ALIMENTATION ARTIFICIELLE DES ALEVINS

Le deuxième ou troisième jour après l'éclosion, encore avant la résorption de la vésicule ombilicale, nous avons commencé à nourrir les alevins intensivement avec du plancton vivant, que nous avons pris dans les étangs d'élevage. Nous avons élevé particulièrement les Protozoa qui ont été donnés aussi aux alevins les premiers jours après l'éclosion.

Les alevins âgés de 5 à 7 jours ont été déposés dans les étangs de ler été. L'élevage ultérieur s'est développé dans des conditions naturelles selon le système complet ou incomplet de Dubisch-Hofer, sous l'influence de facteurs extérieurs positifs et négatifs.

Au cours de cet élevage les pertes étaient souvent considérables et s'élevaient quelquefois à 80-90 pour cent.

Les causes de ces grandes pertes consistent en oscillations de la température d'eau en en quantités insuffisantes de nourriture dans le nouveau milieu ainsi que les ennemis nombreux comme par exemple les têtards, les grenouilles et les poissons sauvages.

Nous allons donner ici un exemple des grandes pertes en citant l'essai de 1961 que nous avons fait sur un étang de ler été à Nasice.

Dénomination	Au total	Le taux des pertes
Les alevins empoissonnés âgés de 5 à 7 jours	500.000	-
C_0 âgés de 5 mois	69.355	86,14 %

En 1964, les résultats sur le même étang étaient plus favorables :

Dénomination	Au total	Le taux des pertes
Les alevins empoissonnés âgés de 5 à 7 jours	87.480	-
C_0 âgés d'un mois	71.628	18,1
C_0 âgés de 5 mois	62.900	28,1

Les pertes étaient petites grâce à la nourriture abondante et convenable dans les étangs et au temps favorable.

6 CONCLUSION

Des résultats des essais faits, on peut conclure que l'application des hypophyses chez les carpes reproductrices traitées a donné en moyenne un taux satisfaisant de l'ovulation.

Les grandes variations dans l'excitation de l'ovulation au cours de certaines années nous indiquent la complexité du problème et dépendent de toute une série de facteurs (biologiques et écologiques).

L'ovulation des oeufs dépend de la condition de la femelle, c'est-à-dire de son état de santé, du stade de sa maturité sexuelle, ainsi que des conditions extérieures. S'il manque un seul facteur seulement des facteurs cités, malgré l'injection des hyphophyses, l'ovulation ne s'effectue pas.

Un des facteurs les plus importants est la maturité sexuelle de la femelle. Cependant on ne peut pas savoir quand elle est arrivée au stade final. Certaines d'elles fraient avant, certaines après, quelquefois même dans un espace de temps de 1 mois.

Un des facteurs négatifs est le mauvais traitement physique des femelles pendant le procédé.

Le problème ultérieur qui est aussi très important consiste en grandes pertes au cours de l'élevage des alevins de leurs premiers jours jusqu'à un mois.

Les causes fondamentales de ces pertes sont en variations de la température de l'eau ainsi qu'en manque de nourriture naturelle au cours de cette période d'élevage. En maintenant une constante température de l'eau, on va éliminer ces pertes.

Prenant en considération les résultats obtenus, nous sommes d'opinion qu'il faut continuer avec des essais de fraie artificielle de la carpe. Notre travail ultérieur consistera en obtention plus élevée du taux de l'ovulation chez les femelles traitées, en accélération de la fraie, ainsi qu'en diminution des pertes au cours de l'élevage des alevins.

Avec la solution des problèmes cités, on pourra appliquer la fraie artificielle de la carpe dans la pratique plus large et résoudre un problème très important de la progression de la pisciculture en eaux douces.

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PRELIMINARY STUDIES WITH THE HYBRID TILAPIA *TILAPIA NILOTICA* X *TILAPIA MOSSAMBICA*

by

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Abstract

Female *Tilapia mossambica* x male *T. nilotica* F_1 hybrids and the reciprocal cross were produced easily by natural spawning. The hybrids grew faster and had a better food conversion than the parent species. They were intermediate between their parents in cold tolerance. Over 70 percent of the hybrids were males. The production of F_2 hybrids was easily accomplished. Over 90 percent were males.

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IV/E-14

ETUDES PRELIMINAIRES PORTANT SUR UN TILAPIA HYBRIDE (TILAPIA NILOTICA X TILAPIA MOSSAMBICA)

Résumé

Des hybrides F_1 de Tilapia Mossambica femelle X T. Nilotica mâle et réciproquement ont été obtenus facilement par reproduction naturelle. Il a été constaté que les hybrides se développent plus rapidement et ont un taux de conversion alimentaire plus favorable que les parents. En ce qui concerne la résistance au froid, ils occupent une position intermédiaire entre les deux géniteurs. Plus de 70 pour cent des hybrides étaient des mâles. Il a été facile d'obtenir des hybrides F_2. Plus de 90 pour cent de ceux-ci étaient des mâles.

ESTUDIOS PRELIMINARES CON HIBRIDOS DE TILAPIA (TILAPIA NILOTICA X TILAPIA MOSSAMBICA)

Extracto

Se han obtenido fácilmente mediante desove natural, híbridos F_1 y recíprocos de hembras de Tilapia mossambica X T. nilotica. Los híbridos se desarrolaron más rápidamente y presentaron una mejor transformación de alimentos que sus progenitores. En cuanto a la tolerancia al frío fueron intermedios entre sus progenitores. Más del 70% de los híbridos fueron machos. Se efectuó fácilmente la producción de híbridos F_2. Más del 90% resultaron machos.

1 INTRODUCTION

Tilapia have been evaluated in the United States by Kelly (1957), Swingle (1957; 1958; 1960), McBay (1961), Shell (1962), and Avault (1965).

Preliminary work has now been completed with Tilapia nilotica x T. mossambica hybrids. The objectives of this study were to: (i) produce hybrids, (ii) compare growth rates, (iii) determine sex ratios, (iv) compare cold tolerances, and (v) determine if the hybrids were fertile. T. mossambica was originally obtained in 1954 from the Steinhart Aquarium in San Francisco, while T. nilotica was obtained in 1957 from Israel.

2 PRODUCTION OF F_1 HYBRIDS

Vinyl-lined pools (2.7 m in diameter and 0.9 m deep) were stocked with parents for both possible crosses. Each pool was stocked with one pair of 13 to 18 cm tilapia. The fish were fed a commercial pelleted feed at a daily rate of 1 percent body weight, five days a week.

Seven spawnings were obtained in 10 pools stocked with female T. nilotica and male T. mossambica. Second spawnings were found in four of the seven pools. Six spawnings were obtained in 10 pools stocked with female T. mossambica and male T. nilotica. Second spawnings were found in two of the six pools.

3 COMPARISON OF GROWTH RATES

The hybrid tilapias and the two parent species were stocked separately in concrete pools at 100 per pool (49,420 per ha). Each stocking was replicated four times. All replicates of the same species or hybrid were stocked with identical weights. All fish were fed a pelleted feed daily six days a week. The initial feeding rate was 10 percent of body weight. This rate was progressively lowered to 6, 4 and 2 percent. High feeding rates were used initially to ensure that enough food was available for the fish to find. Samples of fish were weighed weekly to adjust feeding.

After 83 days the pools were drained and all fish were counted and weighed. Survival, absolute growth or net gain (A), relative growth rate, i.e. $\frac{\text{final weight - initial weight}}{\text{initial weight}}$ (H), and food conversion, i.e. $\frac{\text{kilos food added}}{\text{net kilos fish produced}}$ (S), were determined.

In general the hybrids showed better survival and more efficient food conversions than either of the parent species (Table I). When comparing the relative growth rates (H) both hybrids grew faster than the parent species but adjustments for sex ratios were not made. Male hybrid tilapia grew 2.35 times faster than female hybrids.

4 SEX RATIOS OF F_1 HYBRIDS

The sex ratio for both hybrids was determined by examination of the genital papilla according to Copely (1956) and Lowe (1955). When doubt as to the sex arose, the gonads were examined. Of 328 female T. nilotica x male T. mossambica hybrids examined, 71.6 percent were males. Of 191 female T. mossambica x male T. nilotica hybrids examined, 70.6 percent were males.

5 COLD TOLERANCES

Cold tolerances were determined for the two tilapia hybrids and their parents. Four T. nilotica, averaging 15 cm in length, were stocked in a 40-liter aquarium. The stocking was replicated three times. T. mossambica and the hybrids were stocked in a like manner. All fish were acclimated three weeks at 21.1°C and fed 1 percent of their body weight daily with a pelleted feed. Thereafter, the temperature was lowered 2.8°C within eight hours every seven days. Dead fish were recorded daily (Table II).

Table I

Average growth and survival of tilapia held in concrete pools for 83 days, showing food conversion (S), absolute growth (A), and relative growth (H)

Fish	Stocked		Harvested		S	A	H
	No.	Average weight per fish (grams)	No.	Average weight per fish (grams)			
nilotica x nilotica	100	0.77	80	19.37	0.92	18.50	24
mossambica x mossambica	100	0.85	79	18.12	1.10	17.27	20
female mossambica x male nilotica	100	0.50	94	19.37	0.77	18.87	38
female nilotica x male mossambica	100	0.67	86	19.05	0.85	18.38	27

Table II

Daily mortality of tilapia and F_1 hybrids in aquaria when the water temperature was lowered 2.8°C every seven days

Days in exp.	Temp. °C	Daily mortality			
		T. mossambica	Female *T. mossambica* x male *T. nilotica*	Female *T. nilotica* x male *T. mossambica*	*T. nilotica*
Day 1 to 21	21.1				
44	10.0[1]	1			
45	10.0	2			
46	10.0	5			
47	10.0	2			
48	10.0	2			
	7.2				
49	7.2		4	3	
50	7.2			3	
51	7.2		5	2	3
52	7.2		3	4	1
53	7.2				2
54	7.2				3
55	7.2				3

[1] Third day at 10°C.

In a second test the temperature was lowered 2.8°C every 14 days. Again, dead fish were recorded daily (Table III).

In both tests all fish fed well at 15.5°C. At 12.8°C the hybrids and T. nilotica continued to feed, whereas T. mossambica fed sparingly. They often mouthed the feed pellets only to spit them out.

The period of distress before death was short for T. mossambica whereas the hybrids and T. nilotica often remained on their sides two or even three days before death.

6 REPRODUCTIVE ABILITY OF F_1 HYBRIDS

A test was initiated to determine if the F_1 generation was fertile. Hybrids of each cross were stocked separately in concrete pools without regard to pairing or stocking rates. All available F_1 hybrids were distributed equally into eight pools, four for each hybrid. The fish were fed a maintenance diet. In all eight pools fry were produced. Some pools had several sizes of fry indicating that more than one female had spawned.

7 SEX RATIO OF F_2 HYBRIDS

The F_2 hybrids were stocked in rearing ponds where they were raised to a suitable size for sexing. Of 238 female T. nilotica x male T. mossambica hybrids, 92.4 percent were males. Of 191 female T. mossambica x male T. nilotica hybrids, 89.5 percent were males.

Table III

Daily mortality of tilapia and F_1 hybrids in aquaria when the water temperature was lowered 2.8°C every 14 days

Days in exp.	Temp. °C	Daily mortality			
		T. mossambica	Female T. mossambica x male T. nilotica	Female T. nilotica x male T. mossambica	T. nilotica
Day 1 to 21	21.1				
62	12.8 2/	2			
63	10.0	2			
65	10.0	4			
66	10.0	2			
70	10.0	2			
77	10.0				
79	7.2				
80	7.2		1		1
82	7.2		1		
83	7.2			3	
85	7.2		4	2	1
86	7.2		3	2	2
87	7.2		1	1	
88	7.2		2		
89	7.2			1	
90	7.2			1	
91	7.2			1	
92	7.2			1	
95	7.2				3
	4.4				3
96	4.4				2

1/ Third day at 10°C 2/ Thirteenth day at 12.8°C

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BIOLOGICAL MEANS OF INCREASING PRODUCTIVITY IN PONDS

by

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V/R-1

BIOLOGICAL MEANS OF INCREASING PRODUCTIVITY IN PONDS

Abstract

Various biological procedures and methods of stock manipulation have been employed to increase production in ponds at the Fisheries Research Unit of Auburn University, Auburn, Alabama. These included use of efficient species, efficient species combinations, temporary species, rates of stocking, control of reproduction and increased surface for fish-food attachment.

Most efficient species were those feeding upon plankton. Selective breeding was used to eliminate inefficient individuals in a largemouth bass (Micropterus salmoides) population. Use of parasite- and disease-free fingerlings in stocking also resulted in greater efficiency.

Species combinations including several fishes of different feeding habits gave up to 30 percent increased fish production. A combination of bluegill (Lepomis macrochirus) and largemouth bass plus fresh-water mussels, Lampsilis claibornensis, gave approximately 40 percent increased fish production plus 200 kg/ha shelled mussel meats; it appeared probable that increased fish production resulted from cleaner water caused by the filtration action of the mussels.

Use, in ponds stocked with fingerling bluegill or bluegill-bass, of a disappearing species of fish such as Gambusia affinis or the fathead minnow Pimephales promelas, increased fish production in seven to 12 month experiments by approximately 70 percent. The disappearing species utilized fish-food organisms that were not needed while the fingerling fish being cultured were small and were themselves used as food as these fish became larger. In a Tilapia mossambica - largemouth bass combination, use of the fathead minnow as a disappearing species increased bass production from 21.2 to 108.6 kg per ha (a 400 percent increase), without reduction in tilapia production.

Increasing rates of stocking T. mossambica fingerlings from 5,000 to 10,000 per ha in fertilized ponds increased production in a four-month period by 27 percent. Increasing stocking of fingerling bigmouth buffalo (Ictiobus cyprinella) from 300 to 1,080 per ha in fertilized ponds increased production by 33 percent. In ponds with supplemental feeding, increasing rates of stocking Ictalurus punctatus, the channel catfish, from 560 to 7,500 per ha increased production in nine-month experiments from 302 to 2,646 kg per ha, a 770 percent increase.

Control of reproduction by use of changes in environment, by repression and by predation, while reducing total standing crop, increased production of harvestable-sized fish.

Additional cover or space for fish-food attachment supplied either by brush piles or by limited numbers of dispersed underwater plants increased fish production in fertilized and unfertilized ponds by more than 20 percent; it increased production of a fish-food organism, the fresh-water shrimp (Palaemonetes kadiakensis) 80 to 400 percent.

MOYENS BIOLOGIQUES D'ACCROITRE LA PRODUCTIVITE DES ETANGS

Résumé

Divers procédés biologiques et méthodes d'intervention sur les stocks ont été employés pour accroître la production des étangs du Fisheries Research Unit, dépendant de l'université d'Auburn (Alabama): recherche d'espèces à fort rendement ou de combinaisons d'espèces efficaces, emploi d'espèces transitoires, variation des densités d'empoissonnement, limitation de la reproduction et multiplication des surfaces où peuvent se fixer les organismes servant à l'alimentation des poissons.

Les espèces planctonophages se sont avérées les plus efficaces. Une sélection a été pratiquée pour éliminer les individus inefficaces dans une population de bass à grande bouche (Micropterus salmoides). L'emploi d'alevins exempts de parasites et de maladies lors de l'empoissonnement a également permis d'améliorer les résultats.

Certaines combinaisons comprenant plusieurs espèces de poissons à habitudes alimentaires différentes ont donné jusqu'à 30 pour cent d'augmentation de la production. En associant des bluegill (Lepomis macrochirus) avec des bass à grande bouche et des moules d'eau douce (Lampsilis Claibornensis), on a obtenu environ 40 pour cent d'accroissement de la production de poissons, plus 200 kg par hectare de chair de moules après enlèvement des coquilles; il semblerait que l'accroissement de la production de poissons puisse être attribué à la plus grande propreté de l'eau due à l'action filtrante des moules.

Au cours d'expériences d'une durée de 7 à 12 mois, on a réussi à accroître la production de poissons d'environ 70 pour cent en introduisant, dans des étangs empoissonnés avec des alevins de bluegill ou de bluegill bass, une espèce condamnée à disparaître telle que Gambusia affinis ou Pimephales promelas. L'espèce transitoire se nourrit des organismes que n'utilisent pas les alevins de l'espèce principale tant qu'ils sont petits, puis est elle-même dévorée lorsque ces poissons grandissent. Dans une association Tilapia mossambica - bass à grande bouche, l'utilisation de Pimephales promelas comme espèce transitoire a permis de porter la production de bass de 21,2 à 108,6 kg à l'hectare (augmentation de 400 pour cent) sans réduire pour autant la production de tilapia.

En portant le taux d'empoissonnement de T. mossambica de 5 000 à 10 000 alevins à l'hectare dans des étangs fertilisés, on a pu accroître la production de 27 pour cent au cours d'une période de 4 mois. De même, en portant le taux d'empoissonnement de bigmouth buffalo (Ictiobus cyprinella) de 300 à 1 080 alevins à l'hectare dans des étangs fertilisés, on a pu obtenirun rendement accru de 33 pour cent. Avec alimentation d'appoint, on a réussi, en portant le taux d'empoissonnement d'Ictalurus punctatus de 560 à 7 500 à l'hectare, à faire passer la production, au cours d'expériences d'une durée de 9 mois, de 302 à 2 646 kg à l'hectare, soit une augmentation de 770 pour cent.

La limitation de la reproduction au moyen de changement de milieu, de facteurs inhibiteurs et de prédation, tout en réduisant la masse biologique totale, a eu pour effet d'accroître la production de poissons de taille marchande.

En introduisant dans l'étang des fagots ou un nombre limité de plantes immergées servant de surface de fixation pour les organismes dont se nourrissent les poissons, il a été possible d'accroître la production de poissons de plus de 20 pour cent dans des étangs fertilisés et non fertilisés; ce système a permis d'augmenter de 80 à 400 pour cent la production de crevettes d'eau douce (Palaemonetes kadiakensis), organisme qui sert d'aliment pour les poissons.

V/R-1

MEDIOS BIOLOGICOS PARA AUMENTAR LA PRODUCTIVIDAD EN LOS ESTANQUES

Extracto

Con objeto de aumentar la producción en los estanques del Centro de Investigaciones Pesqueras de la Universidad de Auburn en Alabama, se han empleado varios procedimientos y métodos biológicos de manipulación de las poblaciones. Incluyen éstos el empleo de buenas especies, eficaces combinaciones de éstas, especies de temporada, proporción de indivíduos para poblar los estanques, control de la reproducción y una mayor superficie para la asociación peces-alimentos.

Las mejores especies resultaron las que se alimentan de planoton. Se empleó la selección genética para eliminar los ejemplares ineficaces en una población de perca americana de boca grande (*Micropterus salmoides*). Con el empleo de pececillos pequeños libres de parásitos y de enfermedades, para poblar los estanques se obtuvieron también mejores resultados. Combinaciones de especies, que incluían varios peces de distintos hábitos alimentarios, dieron un incremento del 30 por ciento en la producción piscícola. Una combinación de perca, *Lepomis macrochirus* y de perca americana de boca grande, junto con mejillones de agua dulce (*Lampsilis claibornensis*) aumentó aproximadamente en un 40% la producción de peces, además de 200 Kg/ha de carne de mejillones sin concha; se consideró probable que el aumento de la producción piscícola fuese debido a que el agua era más clara por la acción filtrante ejercida por los mejillones.

El empleo en los estanques poblados con pececillos de *Lepomis macrochirus*, de especies de peces que desaparecen como *Gambusia affinis* o *Pimephales promelas* aumentó la producción piscícola en el 70%, aproximadamente, en experimentos realizados en períodos de 7 a 12 meses. Las especies que desaparecen utilizaban organismos que sirven de alimento a los peces y que no necesitaban mientras los pececillos que se cultivaban eran pequeños, y a su vez eran usados como alimento por estos últimos a medida que crecían. En una combinación *Tilapia mossambica* y perca americana de boca grande, el empleo de *Pimephales promelas* como especie eliminable aumentó la producción de percas americanas de 21,2 a 108,6 Kg/ha (un 400% de aumento), sin reducir la producción de tilapia. El aumento de la densidad de población de pececillos pequeños de *T. mossambica* en los estanques en una cantidad de 5.000 a 10.000 por hectárea en estanques fertilizados, aumentó la producción en el 27% en un período de 4 meses. Al poblarse con mayor densidad los estanques con jaramugos de *Ictiobus cyprinella* a razón de 300 a 1.080 indivíduos por hectárea en estanques fertilizados aumentó la producción en un 33%. En estanques con alimentación suplementaria, las mayores cantidades con que se poblaron los estanques con bagre del canal (*Ictalurus punctatus*) a razón de 560 a 7.500 ejemplares por hectárea, aumentó la producción, en experimentos realizados en 9 meses, de 302 a 2.646 Kg por hectárea, es decir, un aumento del 770%. El control de la reproducción mediante la introducción de cambios en el medio ambiente por represión y por el empleo de especies ictiófagas aunque redujo el efectivo de la población hizo aumentar la producción de peces de un tamaño recolectable. La producción de peces aumentó en los estanques fertilizados y sin fertilizar en más de un 20% mediante la provisión de espacio adicional para la asociación peces-alimento con el empleo de haces de matorral o mediante un número limitado de plantas subacuáticas dispersas; igualmente hizo aumentar la producción en un 80 a 400% del camarón de agua dulce (*Palaemonetes kadiakensis*), organismo que sirve de alimento a los peces.

Many techniques must be employed by the fish culturist to obtain the highest possible yields of fish from ponds. Unproductive natural waters and soils may be improved by the chemical means of liming and fertilization. Production can be further increased by supplemental feeding, and to the highest plateau by feeding in flowing waters to dispose of wastes.

At all levels of fish culture, stock manipulation and other biological means of increasing productivity are of greatest importance in obtaining maximum efficiency in the use of the water and pond space. The various techniques found to be of importance in obtaining high productivity at this Station include use of efficient species, species combinations, temporary species, rates of stocking, delayed stocking, control of reproduction, control of wastes, and use of cover.

1 USE OF EFFICIENT POND FISH

Under this heading come three principal subheadings - species that are efficient because of their feeding habits, because of selective breeding and because of freedom from parasites and disease.

1.1 Efficient species of pond fishes

It is well known in biology that highest production may be obtained by the use of those species with the shortest food chains. In general this indicates that the highest production may be obtained by use of plant-feeding species of fish. Results from a wide variety of species indicate that in general this is true. Maximum production obtained at this Station with species of various feeding habits in fertilized ponds were as follows:

Species	Feeding habit	Maximum production kg/ha
Largemouth bass (*Micropterus salmoides*)	piscivorous	196
Channel catfish (*Ictalurus punctatus*)	insectivorous	370
Bluegill (*Lepomis macrochirus*)	insectivorous	560
Java tilapia (*Tilapia mossambica*)	plankton-feeder	1612

However, it should be pointed out that the Java tilapia is a plankton-feeder and not purely a plant-feeder. In fact, work by Tay (Prowse, 1961) has indicated that several species of phytoplankton ingested by this tilapia are apparently not digested. It is probably true that no species of fish is entirely herbivorous.

The mere fact that a species is at least in part herbivorous does not indicate that it will give highest production under various systems of management. The Congo tilapia (*Tilapia melanopleura*) feeds extensively upon submersed aquatic plants. However, when placed in an environment (fertilized water) where the plants are microscopic, it gives relatively low production because its gillrakers are too widely spaced to enable it to strain and utilize the phytoplankton. It does appear to hold true that the highest production is usually obtained with plankton-feeding species. Where supplemental feeding was used, maximum production with Congo tilapia was 2,240 kg per ha and with Java tilapia was 6,048 kg per ha.

Again, it must be emphasized that a more efficient species at one level of management may not be the more efficient at another level. For example, the bluegill and the channel catfish are both principally insectivorous. In fertilized ponds, the bluegill was the more efficient, yielding 560 kg per ha as compared with 370 kg for the channel catfish. When placed in ponds receiving supplemental feeding, however, the order was reversed, with the channel catfish yielding up to 2,688 kg per ha and the bluegill 896. It appeared probable that the smaller mouth-size of the bluegill made it the more efficient in harvesting natural fish-food organisms, but this was no advantage when supplemental feed was supplied in the form of pellets.

These results emphasize that each species must be tested experimentally for efficiency at different levels of pond culture - in unfertilized ponds, in ponds receiving fertilization and those receiving feeding. It is very important that this testing be done with the principal species present in each country to identify the most efficient fishes. There are at present relatively few species of fishes known to be suitable for pond culture, although many species in the great river systems of each continent would appear suitable. It is important to have a number of efficient yet different species to select from for use in ecologically different waters and for different human preferences.

1.2 Selection for efficiency

Most fish used in pond culture today have not been selectively bred for any purpose, let alone for efficiency. The common carp Cyprinus carpio have been selectively bred for shape, for extent of coverage by scales, and for colour. Most other species used may be considered to be unselected strains of wild fish, although the fish culturist probably selects each year the larger individuals for spawning.

Prather (1951) selectively bred largemouth bass for efficiency of food conversion at this Station. Individual bass in circular pools were fed weighed amounts of small fish twice weekly for periods of five to 12 weeks, and efficiency of gain was determined by dividing weight of fish consumed by gain in weight. The most efficient individuals were spawned and the more rapid-growing of these progeny tested as above for efficiency. This was repeated during a 6-year period. Conversions ranged from 1.5 to 24.2 the first year, and the mean conversions were as follows:

Year	Mean conversion	Standard deviation
1941	7.3	1.20
1942	3.1	0.28
1943	3.9	0.16
1946	5.1	0.50
1947	2.1	0.15
1948	3.4	0.26

Apparently after one year, the most inefficient individuals were eliminated and little change was produced subsequently. The work was discontinued because it was evident that little more could be done without an intensive fish breeding and selection program.

The changes that have occurred in agricultural animals through selection and breeding suggest that this should be a fertile field for improvement of fish stocks.

1.3 Use of parasite- and disease-free fingerlings for stocking

All fish culturists have experienced loss of all or part of a fish crop from parasites and/or disease. The most effective way to reduce or prevent such losses in ponds is to stock only fingerlings that are relatively free of parasites and disease. Clean fingerlings can be provided principally by two procedures. The first is the use of brood fish examined and treated where necessary to rid of parasites and/or disease, followed by early separation of the eggs or young from the parents, and their culture in uncontaminated waters. The second is the chemical treatment of all fingerlings for parasite and disease control before stocking them into production ponds.

At this Station, the earliest experiments with channel catfish were conducted with fingerlings obtained from a river and no treatment was given to free them of parasites. During a three-year test period, each year 50 percent of all catfish died and it was concluded that this species was not suitable for culture in ponds. However, in later years channel catfish fingerlings were treated with acriflavin, formalin and potassium permanganate to rid them of external parasites and disease organisms, followed by treatment with di-n-butyl tin oxide to rid them of intestinal parasites before they were stocked into production ponds. When this was done, survivals ranged from 95 to 98 percent during their growth to marketable size (Swingle, 1958).

Allison (1957) has developed pond treatments that can be applied to control the protozoan ecto-parasites on fish when epizootics develop in the production ponds. External parasites of catfishes have caused poor feed conversions or even extensive fish kills in ponds.

2 SPECIES COMBINATIONS

While the highest production of a single species may be obtained by raising a plankton-feeding fish, highest total fish production per hectare can only be obtained by using a combination of species of different feeding habits.

One of the most important problems in fish culture is to determine just what combinations of species are the most effective in utilizing available fish feeds. Again, this can be determined only by testing in experimental ponds although a certain amount of preselection is possible.

The traditional fish cultures of China and India used species combinations, but these combinations resulted because of occurrence of these species in rivers from which the fish eggs and fry were obtained. Whether these combinations were the most efficient available in each country does not appear to have been measured.

2.1 Combinations of fishes of different feeding habits

2.1.1 Channel catfish (*Ictalurus punctatus*) and Java tilapia (*Tilapia mossambica*)

The channel catfish is insectivorous and utilizes efficiently pelleted fish feeds containing vegetable and fish meals. It was postulated that this species with Java tilapia, a plankton feeder, should make an efficient combination. Where the pond received supplemental feeding, the results per hectare were as follows in a 191-day experiment:

Species stocked	Production	Catfish Feed conversion
1. Channel catfish (4,400)	1,400.0	1.7
2. Channel catfish (4,400)	1,568	1.7
plus Java tilapia (1,250)	266	-

The combination of the two species yielded 1,834 kg compared with 1,400 from the channel catfish alone. There was no difference in feed conversion, assuming all feed was utilized by catfish. The tilapia apparently fed on plankton, wastes, and other fish feeds not utilized by channel catfish.

Both *T. mossambica* and *T. aurea* have been used repeatedly with channel catfish receiving supplemental feeding. Additions up to 2,500 tilapia with 7,500 channel catfish per ha have not measureably affected growth of catfish or feed conversion where it is assumed that catfish consumed all the feed added.

2.1.2 Common carp (*Cyprinus carpio*) and bigmouth buffalofish (*Ictiobus cyprinella*)

The common carp stocked at rates over 240 per ha into fertilized ponds often muddy the water during their feeding activities to such an extent as to interfere with phytoplankton growth. The buffalofish is an omnivorous feeder, which does not burrow in the pond bottom. The results per ha of a 10-month test wer as follows when the pond received 10 applications of 8-8-2 (N-P-K) fertilizer:

	Stocking	Production, kg	
(i)	2,500 common carp		313.6
(ii)	2,500 buffalofish		896.0
(iii)	2,250 buffalofish	745.9	
	plus 250 common carp	179.2	925.1

Here the combination of buffalofish-carp gave approximately the same yield as buffalofish alone, but was much higher than with carp alone and the pond waters remained translucent enough for good plankton production.

2.1.3 Fish and fresh-water mussel

Other animals may be combined with fish in stocking to obtain higher total protein production. An edible soft-shelled mussel, *Lampsilis claibornensis*, was introduced into bluegill-largemouth bass ponds to determine if it could be successfully cultured along with fish. This mussel is used fried or in soups and considered to be a desirable species for culture on account of its market value.

Production of mussels (including shells) per ha in a 12-month period was as follows:

Unfertilized pond	58.2 kg
Fertilized pond	1010.2 "

The mussel was stocked into an 0.8-ha pond along with a standard stocking of per ha of 2,500 bluegills, 1,250 redear sunfish, and 250 largemouth bass. Mussels became very abundant over the pond bottom and were harvested for a period of five years along with the fish. At the end of the sixth year, the pond was drained with the following recovery per ha:

Total fish	464.4 kg
Total mussel meat	399.6 "

The total weight of mussel plus shells was 1,270.8 kg per ha, of which the shucked weight of meat was 31.5 percent. In addition to the fish recovered on draining, an additional 139.7 kg per ha had been removed by fishing. The average standing crop of fish where no mussels were present was 316.6 kg per ha (Swingle, 1961). In this case the presence of mussels appeared to increase fish production.

It is postulated that the apparent increase was real and probably caused by cleaner water resulting from the filtering action of the 49,440 mussels per ha distributed over the pond bottom. Their combined effect in filtering out the detritus and organisms upon which they feed should have helped to reduce the waste materials that are a limiting factor in fish production. The effectiveness of these and other animals in maintaining cleaner pond waters should be a rewarding field of research.

It is noteworthy that the difference in production obtained from Congo and Java tilapia receiving daily feeding, as mentioned in Section 1.1, appeared to depend upon their relative ability to maintain clear water. The Java tilapia feed upon artificial feeds, decaying organic matter, their own faeces and upon plankton. Consequently, they can be fed at a high daily rate because the pond bottom and waters are kept clean.

2.2 Combination with fishes that disappear from the combination

A problem in maximum utilization of all food in a pond is that when fingerling fish are stocked, and their combined weight is small, much food currently available is not utilized. Food is lost by emergence of adult insects, by decay and incorporation into the bottom muds, by denitrification, and other processes. A small amount is recycled into fish foods at a later date, but not in amounts to make up for inability of fish to utilize it during this early period.

One solution would be to stock more fingerlings, but if too many are stocked, none may reach a desirable size. Another solution is to stock the desired species in combination with another species that reproduces verv early, is efficient in harvesting the otherwise wasted fish-food organisms and remains small enough to be consumed when the principal species becomes larger and food per individual is more scarce.

2.2.1 Bluegills plus *Gambusia*

In a seven-month experiment in fertilized ponds using 3,900 bluegill plus 1,625 *Gambusia affinis* per hectare, average production per ha was:

Bluegill	186.4 kg
Bluegill plus *Gambusia*	349.4 "

The two-inch bluegills plus *Gambusia* adults were stocked on May 2. The *Gambusia* began producing young on June 1, and became very abundant by late July, when their numbers began declining. When the pond was drained on November 14, practically all the *Gambusia* had been consumed by bluegills.

2.2.2 Bluegill-bass plus fathead minnows

The fathead minnow (*Pimephales promelas*) appeared more desirable for this purpose than *Gambusia* since the former began spawning in March and the latter in June. Average production per ha for a 12-month period in fertilized ponds stocked with 3,750 bluegill fingerlings (five cm), 134 largemouth bass (two cm), and with or without fathead minnows (1,000 and 2,500) were as follows:

Bluegill-bass	282.6 kg
Bluegill-bass-fatheads	470.6 "

The fathead minnows and bluegill fingerlings were stocked in December, with the small fingerling bass added in May. Fatheads spawned in March and became exceedingly abundant. The numbers began to decline early in July, from predation upon them by both the bass and the bluegills. Few remained when ponds were drained in October-December. They contributed enough extra fish foods to increase average production by approximately 66 percent.

2.2.3 Tilapia-bass plus fathead minnows

Tilapia at this Station overwinter in warm water and are stocked into ponds in April. Largemouth bass fingerling are added in May. One year a pond was stocked with 2,500 Nile tilapia, 2,500 Jave tilapia plus 500 largemouth bass per ha. The next year it received the same stocking of Nile and Java tilapia and bass, plus 2,500 Congo tilapia and fathead minnows. The fathead minnows were in the pond in January of the same year, being escapees from draining a fathead pond above. They were used to harvest fish-food organism produced in the pond prior to stocking the tilapia. Since tilapia were primarily plankton feeders, the fatheads plus any young tilapia hatched in the pond were principally food for the young bass. Each year the fish received supplemental feeding from May to November, when the pond drained. The results were as follows:

Experiment	Production per ha, kg Tilapia	 Bass
Without fathead minnows	2,118.0	21.2
With " "	2,182.7	108.6

The addition of fathead minnows resulted in an increase of 87 kg largemouth bass per ha, without reducing the production of tilapia.

2.2.4 Channel catfish-bass plus fathead minnows

Originally, 2,500 fathead minnows were added with 7,500 channel catfish per ha in ponds receiving supplemental feeding with the expectation that they would be eaten by catfish. This did not occur; therefore, they were utilized by stocking 125 largemouth bass per ha. In a period of seven years this had added an average of approximately 45 kg per ha of bass to each crop of catfish without interference with the growth or production of the latter.

This method of making more efficient use of unused fish feeds in ponds would appear worthy of more extensive testing and use.

3 RATES OF STOCKING

Rates of stocking of fish are extremely important at all levels of fish culture. If too few are stocked, the results are large fish and low production. If too many are stocked, the result may be high production, with fish of undesirable size.

3.1 In unfertilized and fertilized ponds

The problem of how many fish to stock is most troublesome in unfertilized and in fertilized ponds. If the number of fingerling carps is stocked so that 200 g carp will be produced by the end of the growing period, then fish foods produced by the pond are being wasted during a considerable portion of this time. This is true because the carp normally eats not more than five to eight percent of its own weight daily, and when small, little feed is required. In natural populations, this problem is solved by spawning; then thousands of young fishes are available for harvest of the fish-food organisms. As fish grow larger and require more food, this problem is solved by reduction of small fishes by predation. This is a similar solution to that presented in section 2.2 by the use of the fathead minnows as a disappearing species.

If enough number of carp are stocked to consume the current fish-food production, there will be insufficient food to raise them to a desirable size.

This was illustrated by experiments at this Station on rates of stocking Java tilapia in fertilized ponds during a four-month period (Swingle, 1960). The results per ha were:

Number stocked	Fish production, kg Total	 harvestable 1/	Percentage harvestable
5,000	316.2	309.1	97.5
10,000	403.2	203.4	50.4

1/ Tilapia averaging 45 g or more.

In experiments with various rates of stocking bigmouth buffalofish, results from a six-month growing period in fertilized ponds (Swingle, 1957b) were per ha:

Number stocked	Average weight stocked, g	Production kg	Average size g
300	22.7	151.6	636
600	22.7	273.5	603
1,080	22.7	656.5	590

In this case, since the final sizes were approximately equal, the maximum rate of stocking probably could have been somewhat higher. The two lower rates of stocking (300 and 600) required another seven months of growing season to reach approximately the same standing crop as was achieved in six months at the highest rate of stocking. It is evident that in determining rates of stocking for various levels of management, a range in rates of stocking must be tested to enable selection of the maximum rate producing desirable-sized fish in a minimum period of time.

3.2 In ponds with feeding

Supplemental feeding enables the fish culturist to use natural fish-food organisms more efficiently. In a direct way he can do what nature does in natural populations in a roundabout way. In section 3.1 it was pointed out that in natural populations small fishes hatching in the spring harvested economically the fish-food organisms and as some became larger, a larger share of the food was made available to them by reduction in the numbers of fish. This reduction is accomplished by predation, often ably assisted by various other causes of "natural mortality." With supplemental feeding, the fish culturist can stock larger numbers of fish per ha to more fully utilize natural fish-food organisms. As fish grow larger, he can supply increasing amounts of supplemental feed to bring them to harvestable size.

3.2.1 Experiments with catfishes

With daily supplemental feeding, large numbers of fingerling fish, or larger fish, must be stocked if high production is to be achieved. In early experiments at this Station, the channel catfish was stocked at 560 fish per ha and given supplemental feeding. The species was discarded as of little value for commercial use because production per ha was only 302 kg. Later work with the speckled brown bullhead (*Ictalurus nebulosus marmoratus*) demonstrated the important relationship between stocking rates and production with feeding (Swingle, 1957a). Results per ha are given below for a one-year period during which fish received daily supplemental feed while water temperatures remained above 16°C:

Rate stocked	Fish produced, kg
2,500	631.7
5,000	840.1
7,500	1,011.8
15,000	1,387.0

With this information, it was immediately suspected that low production obtained with channel catfish and feeding was the result of the low rate of stocking. Testing with this species was then resumed at various rates of stocking and with supplemental feeding. The channel catfish was then found to be a high producer and most economical in food conversion, directly contrary to the former conclusion. Results for an 8.5-month experiment per ha were as follows (Swingle, 1958):

Rate stocked	Kg fish produced
2,500	1,076.7
5,000	1,709.7
7,500	2,646.6

3.2.2 Experiments with tilapia

Similar results were obtained in experiments with both the Java and Nile tilapia (Swingle, 1960). Fingerlings were stocked at various rates per ha in ponds that had been fertilized. In addition, the fish were fed a supplemental pelleted fish feed. Production per ha in a period from 111 to 123 days was:

Species	Number stocked	Production kg	A_T	"S" Conversion
Java tilapia	10,000	563.6	98.7	2.57
"	20,000	1,601.7	99.7	1.67
"	25,000	1,999.9	88.9	1.10
"	50,000	3,299.1	67.7	1.10
Nile tilapia	20,000	1,546.7	98.5	1.80
"	40,000	2,665.5	91.9	1.35

The fish culturist still has several factors that limit the number of fish he can grow to harvestable size. He must stay within the feeding rates that give economical conversion, and the maximum amount of feed he can add daily is limited by the type of feed and by the "sewage disposal" system in his pond. With flowing water to remove wastes and to supply oxygen, safe feeding rates rise to a high level. Without flowing water to remove wastes, he is limited by the capacity of his pond system to minimize and to destroy wastes. The Java and Nile tilapia are among the most efficient of fishes in minimizing wastes; consequently they can be fed at high rates to obtain high production. However, even here a limit exists beyond which it is not safe to feed. Although the stocking per ha of 50,000 fingerling Java tilapia gave highest production, it was not possible to increase feeding to where more than 67.7 percent (A_T) of the weight was fish of harvestable size (i.e. weighing 45 g or more). Combinations of species giving more efficient disposal of wastes in impounded water or other methods of waste destruction are needed to attain higher levels of production.

4 CONTROL OF REPRODUCTION

While control of reproduction would probably decrease weight of the entire standing crop, it makes possible production of fish of desirable size. This is especially important with use of supplemental feeding where the feed must be utilized to produce marketable fish. Various methods of population control have been used in fisheries.

4.1 Change of environment

This method is widely used in pond fish culture. Milkfish (Chanos chanos), which spawn only in the oceans, are cultured in brackish-water ponds along the Asiatic Coast. In Chinese and Indian pond cultures carps that spawned in flooded rivers but would not spawn in ponds are used. Channel catfish and buffalofish used at this Station also were river fishes and seldom spawned in production ponds. Lack of ability to spawn in the pond environment made many of these fish excellent species for pond culture.

4.2 Repressive factor

Both common carp and buffalofish normally failed to spawn in waters in which they had been held for several months prior to the spawning period, but spawned readily when transferred to fresh water. This effect was attributed to the repressive effect of excretions from these species (Swingle, 1956). A method of culture for speckled bullhead was devised by stocking fingerlings at different rates to determine the rate at which there was no or little spawning while the fish were still not too crowded for satisfactory growth. For this species the stocking rate of 7,500 per ha accomplished this purpose (Swingle, 1957a).

Nile tilapia fingerlings stocked at 20,000 or more per ha grew satisfactorily with supplemental feeding, but failed to reproduce (Swingle, 1960). However, Java tilapia still reproduced at stocking rates of 50,000 per ha.

4.3 Use of fish too young to spawn

A culture method was devised for the brown bullhead by stocking two to five cm fingerlings in June, feeding to obtain rapid growth, followed by harvest the next May before reproduction could occur (Swingle, 1957a).

A similar method was used for Java and Nile tilapia by stocking in May and harvesting at 15 to 20 cm total length the following October (Swingle, 1960). Light spawning occasionally occurred with the Java tilapia, but insufficient young were produced before draining to interfere with production of larger fish.

These methods have the disadvantages of producing relatively small harvestable fish (50 to 200 g), and harvest must be in a fixed period just before spawning. This prevents the fish culturist from holding his crop to obtain higher prices when the market is low.

4.4 Use of piscivorous fishes

Piscivorous fishes are used in fish culture to reduce the numbers of young so that the older fish may reach a desirable size. In European carp culture, the pike *Esox lucius* or pike-perch *Lucioperca sandra* was used to eliminate small carp that resulted from unexpected spawning and wild fishes that entered the pond (Schäperclaus, 1933).

At this Station largemouth bass have been used with catfishes, tilapia, carp, and other species for a similar purpose and also to increase overall production of desirable species (Swingle, 1957a,b; 1958; 1960).

5 ADDITIONAL SURFACE FOR FISH-FOOD ORGANISMS

In many fertilized ponds, almost the entire bottom contains individual fish-food organisms in close proximity. It appeared, therefore, that "floor" space was a limiting factor and that the addition of various materials would greatly increase surface for attachment and might increase production.

5.1 Fresh-water shrimp and bluegills

Experiments were conducted with fresh-water shrimp *Palaemonetes kadiakensis* and the bluegill in ponds with and without cover in the form of brush piles or a mixture of aquatic plants *Chara*, *Najas*, and *Cabomba*. The stocking (2 May) per hectare was 3,750 bluegills weighing 53.7 kg and/or 65,000 shrimp weighing 21.7 kg; ponds were drained in November. Fertilized ponds received 10 applications of 7-8-2 fertilizer at the rate of 112 kg per ha. The results were as follows:

Unfertilized ponds	Production per ha, kg Shrimp	Bluegill
Shrimp	45.4	
Shrimp with plants	236.7	
Bluegill		112.0
Bluegill plus plants		140.7
Bluegill plus shrimp plus plants	182.0	263.9
Fertilized ponds		
Shrimp	637.7	
Bluegill plus shrimp	104.9	235.9
Bluegill		154.3
Bluegill plus shrimp plus brush	1,173.5	236.8

The presence of rooted or attached aquatic plants filling less than 50 percent of the water volume increased both shrimp and bluegill production in unfertilized ponds. Subsequent experiments indicated that the increase came principally from the presence of Chara, while Najas did not increase production. Highest bluegill production was with Chara plus shrimp.

In fertilized ponds, the presence of shrimp increased bluegill production 60 percent. When cover (attachment surface) was provided by filling the pond to water level with loosely-piled brush, the added surface caused production of 10 times the weight of shrimp but no increase in weight of bluegills above that in the shrimp-bluegill pond without cover. However, all bluegills in the pond with cover were large, while those in the pond without cover included a high percentage of small bluegills. Cover was thus effective in greatly increasing a fish-food organism, the fresh-water shrimp, and increased the harvestable crop of bluegills.

5.2 Bluegill-largemouth bass

Four ponds were each stocked with 3,750 bluegills per ha in December plus 300 largemouth bass fingerlings in May. Three of these ponds were without cover and one was filled with brush to the water level in the shallow half of the pond. After draining in October, the latter pond was restocked the following season exactly as above, except that 600 largemouth bass fingerling were added. All ponds received standard fertilization. The average results were:

Stocking	Cover	Production per ha, kg
Bluegill plus bass (300)	None	282.6
Bluegill plus bass (300)	Yes	492.8
Bluegill plus bass (600)	Yes	439.0

Again, it is quite evident that "cover" or added surface provided by brush was effective in increasing total fish production very materially (65 percent). The amount of added surface or "cover" needed for highest production and methods of supplying it are interesting subject for research. These experiments suggest that submersed aquatic plants and brush served the same purpose. It is postulated that the increased production resulted because of increased attachment surface for fish-food organisms. Since brush or flooded trees decay rapidly, they lose most of their effectiveness within a few years. It would appear that submersed rooted aquatic plants would be the cheapest and best for adding attachment surface, provided species can be found that do not become so abundant as to exclude fish from large areas of the pond.

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V/R-2

MIXED FISH CULTURE -
AN ECOLOGICAL APPROACH TO INCREASE POND PRODUCTIVITY

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Abstract

Mixed fish culture is one of the important management techniques to utilize all resources in a pond to produce fish. Fertilization and feeding increase the carrying capacity of the pond, but only a mixed population of ecologically different species, will utilize in the most efficient way the enriched food niches.

The state of mixed fish culture in the Mediterranean countries is surveyed. Among the 15 countries under survey, no fish culture exists in seven countries, fish culture is at its start in five, and only three countries have reached a developed stage. In France and Yugoslavia, the mixed fish population is composed of carp as the main species and tench as an additional one. In some instances pike and pike perch serve as "police" fish. In Israel the mixed fish population is composed of carp as main species and tilapia or grey mullet as an additional one.

The existing three different approaches to mixed fish culture are analyzed. It is pointed out that the differences in approach are the result of the influence of different socio-economic, climatic and biological factors.

The essential feature of the far eastern system of fish farming is the small-sized pond stocked with five to six selected fish species, with different feeding habits. The well cared and managed pond gives a high production, averaging 3,000 kg/ha.

The European fish culture system is characterized by big ponds (50-200 ha), with a long rotation period. Carp is the dominant cultivated fish; the additional fish species are of minor importance. Attempts are made to culture plankton-feeding fish along with carp. Fish production is based, to a large extent, on natural food.

The Israeli fish culture system is featured by the very intensive management of moderate-sized ponds (4 to 6 ha), stocked with two sizes of carp and either tilapia or grey mullet. The stocking policy is to adjust the numbers of each fish group to minimize the intra-specific competition and restrain the inter-specific competition, enabling full utilization of resources. Production of 3,000 kg/ha and over is obtained.

A method to evaluate the efficiency of mixed fish culture in increasing fish production in ponds is proposed.

LA PISCICULTURE MIXE - UNE METHODE ECOLOGIQUE EN VUE D'AUGMENTER LA PRODUCTIVITE DES ETANGS

Résumé

La pisciculture mixte est une technique d'aménagement visant à l'utilisation de toutes les possibilités d'un étang pour la production de poisson.

La fertilisation et l'alimentation augmentent la capacité des étangs, mais seulement une population de poisson composée d'espèces écologiquement différentes peut utiliser d'une façon efficace les niches riches en aliments.

On a étudié l'état de la pisciculture mixte dans 15 pays de la région méditerranéenne; dans 7 de ces pays, elle n'existe pas; dans cinq, elle en est à ses débuts et dans trois pays, elle est développée. En France et en Yougoslavie, la pisciculture mixte est faite en partant de la carpe comme poisson principal et de la tanche comme poisson d'accompagnement. Souvent, le brochet et le sandre servent comme "poissons policiers". En Israel, la pisciculture mixte tient la carpe comme poisson principal et le tilapia et le mugil comme poissons d'accompagnement.

Les trois méthodes différentes d'étudier la pisciculture mixte sont analysées. Il est souligné que l'emploi de ces différentes méthodes est le résultat de facteurs sociologiques, climatiques, biologiques différents.

Le facteur essentiel de pisciculture en Extrême-Orient est le petit étang stocké de cinq ou six sortes de poissons sélectionnés, ayant un régime alimentaire différent. Un étang bien aménagé et tenu produit jusqu'à 3000 kg/h de moyenne.

Le système de pisciculture européen est caractérisé par de grands étangs (50-200 h), avec une longue période de rotation. La carpe est le poisson principal et les autres sont moins importants. De grands efforts sont faits pour y introduire les poissons planctophages avec la carpe. La production est basée sur l'alimentation naturelle.

Le système israélien se caractérise par l'exploitation poussée d'étangs de grandeur moyenne (4-6 h), stockés de deux tailles de carpes avec, comme poisson d'accompagnement, le tilapia ou le mugil. La politique d'aménagement des étangs est de fixer le nombre d'individus d'une espèce ou entre les espèces et permettre la plaine utilisation des ressources. La productivité passe ainsi à plus de 3000 kg/h.

Une méthode pour l'évaluation de l'efficacité de la pisciculture mixe sur la production des étangs est proposée.

V/R-2

PISCICULTURA MIXTA
ESTUDIO ECOLOGICO PARA AUMENTAR LA PRODUCTIVIDAD DE LOS ESTANQUES

Extracto

La piscicultura mixta es una de las técnicas importantes de ordenación para utilizar todos los recursos en un estanque destinado a producir peces.

La fertilización y la alimentación aumentan la capacidad de producción del estanque, pero sólo una población mixta de especies ecológicamente distintas aprovechará del modo más eficaz los sectores del estanque en que abundan más los alimentos.

Se estudia el estado de la piscicultura mixta en los países mediterráneos. Entre los 15 países estudiados, la piscicultura no existe en siete de ellos, se halla en sus comienzos en cinco, y solamente tres países han llegado a una fase desarrollada. En Francia y Yugoeslavia, la población de peces mixta se compone de carpas, como especie principal, y de tencas como especie adicional. En algunos casos, el lucio y el lucioperca sirven como peces "policias". En Israel, la población mixta de peces se compone de la carpa, como especie principal, y la tilapia como especie adicional.

Se analizan los actuales tres distintos métodos que existen en relación con la piscicultura mixta. Se indica que las diferencias de método son el resultado de la influencia de los distintos factores socio-económicos, climáticos y biológicos.

El rasgo esencial del sistema seguido en el Lejano Oriente en la piscicultura, es el estanque de pequeño tamaño poblado con cinco o seis especies seleccionadas de peces de diferentes hábitos alimentarios. El estanque bien cuidado y administrado da una producción elevada, que es por término medio de 3.000 kg por hectárea.

El sistema piscícola europeo se caracteriza por estanques grandes (50-200 hectáreas), con un largo período de rotación. El pez que se cría con carácter predominante es la carpa; las especies de peces adicionales son de menor importancia. Se está tratando de cultivar junto con la carpa, peces planctófagos. La producción pesquera se basa, en gran medida, en alimentos naturales.

El sistema piscícola israelí se caracteriza por una explotación muy intensiva de estanques de tamaño medio (4-6 hectáreas), poblados con dos tamaños de carpa junto con tilapia o mújol. El criterio seguido respecto a la densidad de repoblación consiste en ajustar el número de cada grupo de peces para reducir al mínimo la competencia intraespecífica y restringir ésta permitiendo el aprovechamiento de los recursos. Se otiene una producción de 3.000 Kg/ha y aún más.

Se propone un método para evaluar la utilidad de la piscicultura mixta para aumentar la producción íotica en los estanques.

1 MIXED FISH CULTURE, SYNONYMS AND CONCEPTS

Association of fish species (Far Eastern countries), polyculture (Europe - U.S.S.R.), mixed fish culture (Mediterranean - Israel) are synonyms for the idea that if several fish species of different feeding habits and behaviour are reared together, the result will be increased fish production.

Whilst in the U.S.S.R. and Israel the main fish is the common carp, in the far eastern countries the common carp plays a smaller role in the fish association. Another synonym which expresses the same idea from a different angle, but is generally associated with a certain definite fish population other than carp is the concept of a balanced fish population (U.S.A. - Swingle, 1950).

The goal of rational pond management is to utilize the existing conditions in the pond to produce fish up to its carrying capacity. The carrying capacity of the pond when applied to a certain definite species, means the carrying capacity of the ecological niche in which this species lives. This can be increased through man's intervention, by administration of fertilizers or addition of feed, etc. (Yashouv, 1959). These various treatments create better conditions in the pond, improve the rate of fish growth and provide 'living space' for a denser fish population. Increased stocking will lead to greater utilization of the capacity of the water body to sustain fish life and the growth of the stock under the newly created conditions.

However, higher stocking density per unit area will not lead to more efficient utilization of the pond as a whole, but its effect will be concentrated mostly on the particular ecological niche specific to the fish species stocked. The "grand total" capacity of the pond to produce fish is the sum of production of different ecological niches existing in the pond. Thus a mixed stock of selected fish species, with complementary feeding habits and different ecological requirements, will fill the different ecological niches in the pond and utilize in the most efficient way all life requisites existing in the pond for fish production.

The idea of mixed fish culture has its roots in ancient China. The belief of Chinese fish farmers that the greatest fish production can be achieved only when several fish species of different habits are stocked together, species which occupy "different strata" of water, expresses the ecological approach to the utilization of the various ecological niches in the pond by the use of fish with different ecological requirements.

Because of the different feeding habits and behaviour of the fish used in mixed fish culture, no serious competition will occur between the different fish groups. On the contrary each group may have a positive influence on the growth and production of the other.

This statement that ecologically different fish species will not compete will only remain true within the limits of a certain density of stocking or food supply etc. With an increased stocking density, beyond the carrying capacity of the pond, inter-specific competition will start, intra-specific competition will increase, and fish production will slow down.

Consequently, it is not enough to select proper species for the fish associations. The developing inter-relationships between, and within, the different fish groups in ponds must be studied on a quantitative basis, and proper numbers for stocking under different conditions must be worked out if we are to manage the pond resources with efficiency.

2 THE STATE OF MIXED FISH CULTURE IN THE MEDITERRANEAN AREA

2.1 Scope of the survey

This paper concerns only warm-water fish culture in ponds, which in Mediterranean countries is mainly cypriniculture and that of associated fish groups. The management of fish populations in lakes, barrages and other water accumulations, although regarded in some countries (U.S.S.R.) as fish culture, is excluded from the present survey.

Very little information is available on fish culture in Mediterranean countries, particularly on mixed fish culture, but the availabe data are summarized in Table I. These data were gathered from a distributed questionnaire, FAO technical assistance project reports, incidental papers and personal communications. The countries fall into three categories: (i) those without any fish culture, (ii) those where it exists but is of minor importance in fish production of the country, and (iii) those where it is developed and progressive, contributing an important share in total fish production. In only three of the countries listed in Table I, Israel, Yugoslavia and U.A.R., does fresh-water fish contribute a high proportion (35 to 65 percent) of the total fish production of the country. Only in the two former (Israel and Yugoslavia) is fish culture important. In U.A.R. the fresh-water fishes come from lakes and rivers.

In most of the countries of the region no mixed culture of carps and other species exists, although in some countries carp are cultured in rice fields.

Table I

The state of mixed fish culture in the Mediterranean area
(Warm-water species)

Country	No fish culture	Starting fish culture	Developed fish culture	Mixed fish culture
Morocco	+			
Algeria	+			
Tunisia	+			
U.A.R.		+		+
Israel			+	+
Iraq		+		
Syria		+		
Lebanon		+		
Turkey	+			
Bulgaria		+		
Greece	+			
Yugoslavia			+	+
Italy	+			
France			+	+
Spain	+			

In U.A.R., Syria, Iraq and Lebanon, fish culture is in its infancy. Experimental fish farms are starting cypriniculture, Tilapia culture and mixed fish culture of different species of carp.

2.2 Countries with developed fish culture

2.2.1 Fish culture in France is of minor importance in total fisheries production, only about 2.0-2.5 percent. Fish ponds total 10,000 ha of which 80 percent is used for mixed fish culture (Table II). Production per unit area has increased compared with data given by Lecrointre (1949) but is still low, 140 kg/ha/year.

Table II

Mixed fish culture in France

(Based on information obtained through a questionnaire distributed by Vivier *et al.*, in 1961)

	Fish pond area in ha	Production in kg	Production kg/ha	
Total	100,000	14,000,000		
Monoculture: carp K1	20,000	4,000,000	200	
Mixed fish culture: Carp K2	80,000	10,000	60	125
Rutilus rutilus			35	
Tinca tinca			20	
Esox, Sander, *Perca*, etc.			10	

The slow development of fish culture in France is probably due to the fact that carp is in less demand than other species (Vivier, 1954). To increase fish pond productivity and utilization of natural food, ponds are stocked with carp, tench and *Rutilus*. The rate of stocking is adjusted to exclude inter-specific competition. Undesirable species or trash fish are controlled and utilized by introduction of predatory species like *Esox*, sander and black bass. The following serves as an example of the stocking rate practised in France:

Carp K2	(150-250 g)	- 250 per ha
Tench	(100 g)	- 200 per ha
Esox	(100 g)	- 15 per ha

The higher production of carp in monoculture, as shown in Table II, is due to the fact that carp monoculture is applied to selected K1 carp only, and only the most productive fish ponds are chosen for monoculture.

2.2.2 *Fish culture in Yugoslavia* is of the intensive type of farming. Fertilizers and additional feed are used to increase fish production. Pond fish production is about 20 percent of total fish production in the country.

Mixed fish culture in Yugoslavia in 1962 comprised an area of 7,500 ha with a total production of 7,500,000 kg. The total pond fish production consisted of 90 percent carp and 10 percent *Tinca tinca*, *Silurus glanis*, *Lucioperca lucioperca* and *Esox*. During the last five years the Yugoslavian fish culture has undergone considerable changes. The stocking rate has been increased almost three times and the time of fish production to a marketable size has been shortened from three to two years.

As an example, the stocking rate practised in two leading fish farms in Yugoslavia - Koncanica and Poljana may be cited. In 1960 the carp stocking density was 500 to 600 per ha (the density depending on the availability of stocking material). The stocking rate of other species varies, but is about 10 to 20 percent of the carp population. The stocking rate of the additional fish species is influenced by the experience of the local fish farmers, the success of spawning and fry availability. Generally the fry of these species are obtained from wild spawning in the fattening ponds.

The selection of additional fish species to carp was done with the idea that the tench will utilize the food left over by the carp and pike-perch and will control the population of small trash fish like *Leuciscus* sp., *Scardinius* sp., and others, which enter the ponds with the water supply. Increasing the stocking density, in spite of the additional feeding of the fish, revealed the existing competition between carp and tench.

Carp-tench competition becomes conspicuous when fish numbers per unit area are increased. This competition depresses carp production. As the tench is a slow grower its production cannot fill in the loss of carp production due to carp-tench competition. The condition in ponds becomesmore severe with the wild spawning of tench and over-crowding the ponds with small slow growing tench (Livojevic, 1965). Although this fact was recognized by the leading fish culturists in Yugoslavia, tench culture with carp is still continuing, because of the demands of the foreign market. The facility of carp marketing together with tench (due to foreign market demands for tench) and the high price of tench, compensate to some extent for the loss of carp production due to carp-tench competition, but this is not the solution to the biological problem of increasing pond productivity. To solve this problem, the Yugoslavian fish culturists looked for a herbivorous or plankton feeding fish to use in mixed fish culture with carp.

Since 1962 systematic experimental work is being done on the introduction of grey mullets into fish ponds (Morovic and Sabioncello, 1963; Morovic, 1963; Sabioncello, 1964). The work with grey mullets comprises studies on the distribution of grey mullet fry along the Adriatic coast, ways of fry transport from sea coast to the fish ponds over distances of several hundred kilometers, acclimatization to fresh water, and growth studies. The first results of this work reveal good prospects for grey mullet culture in fish ponds in Yugoslavia. Fry are available along the Adriatic coast; losses of fry during transport and acclimatization to fresh water are negligible.

The growth of Mugil cephalus fry is fast, the average daily increment in the first four months after stocking being 1.4 g. The problem to be solved is the high loss of the mullets during this period of growth. It is believed that the mullet fry are preyed on by Silurus glanis and Lucioperca.

Grass carp (Ctenopharyngodon idella) are also being tried. A consignment of grass carp fry was shipped to Yugoslavia in November 1963. In May 1964 these fingerlings were stocked in ponds. The growth rate of this fish surpassed that of carp, averaging 6.1 g per day during the five months following stocking (Disalov, 1965). This growth rate is evidence that conditions are suitable for grass carp in Yugoslavian waters.

2.2.3 Fish culture in Israel is of the intensive type. Fish ponds are fertilized systematically with ammonium sulphate or liquid ammonia, superphosphate and chicken manure at bi-weekly intervals during the growth season. The fish are fed daily. Ponds are stocked with two size groups of carp, fattening fish and fingerlings.

Fish are removed from ponds twice a year, either by thinning out all of marketable size, or by draining the pond removing all the fish and stocking again with undersized fish for further growth. This intensive fish farming resulted in a yearly fish production of 2,000-2,100 kg per ha. Under these conditions of intensive farming the use of mixed fish culture to raise pond productivity above the attained level has to be carefully planned.

Plankton investigations conducted in fish ponds in Israel, in the early fifties, showed the need for an additional fish to exploit this source of food (Wirszubski and Sarig, 1953). But the danger that any mistake in management in densely stocked ponds might cause a sharp decline in pond productivity, and slow down the development of mixed fish culture in Israel, was also recognized.

Many attempts to select proper fish species for culture together with carp were made. Experiments were conducted with: tench, Tinca tinca (Hoffenberg, 1949; 1951); big mouth buffalo Megastomatobus cyprinella, the Indian carp, Catla catla (Yashouv, 1958a); Tilapia galilaea (Ben-Tuvia and Hoffenberg, 1951; Reich, 1954; Sarig, 1955; Yashouv, 1956; 1958b); Tilapia aurea, known formerly as T. nilotica (Yashouv, 1958b; 1959; 1963; 1965); Mugil cephalus (Anon., 1948; Perlmutter et al., 1956; Pruginin and Kitai, 1957; Yashouv, 1957, 1958c; 1965a). The following principles were formulated to guide the selection of additional fish to carp:

(i) The additional fish has to utilize the resources of natural food in ponds not used by the carp.

(ii) This fish should attain marketable size together with the carp, so that all the fish in the pond can be marketed at once after draining the ponds.

(iii) Carp production in ponds should not be affected by the influence of the additional fish because of food competition, overcrowding by wild spawning and so on.

(iv) The additional fish should be capable of adjusting itself to the ecological conditions of carp ponds and to grow well in these conditions.

In accordance with these principles tench and bigmouth buffalo were withdrawn from cultivation. In the existing conditions in ponds in Israel both species exhibited slow growth, especially the tench (0.1 to 0.9 g per day). They feed on the same natural food as the carp, and they use additional feed as the carp, but the food conversion is very poor. The buffalo is very susceptible to the external parasite Lernaea and fetched low prices on the Israeli market.

The cultivation of tench encountered some other difficulties - high losses during the fattening period, sometimes reaching 90 percent and the difficulty of securing enough fry for stocking, as the spawning was irregular.

The experiments with grass carp and Catla catla were preliminary only and were discontinued as the experimental stock died and no replenishment was obtained.

Tilapia galilaea is a promising fish; its feeding habits differ from that of T. aurea, as it is strictly a plankton feeder, but more experimental work is necessary to clarify its role in the fish association in ponds.

Tilapia aurea and Mugil cephalus were found to be the most suitable for the requirements of mixed culture in Israel. Under comparable experimental conditions the addition of T. aurea increases fish production by about 30 percent. In commercial fish ponds the exact evaluation of increase is difficult because of differences in growing conditions and management in mono-culture and mixed culture. In commercial fish farms 1,000-1,500 Tilapia fingerlings (young-of-the-year) are stocked per ha together with two carp size groups, whilst in experimental fish ponds 2,550-3,000 young-of-the-year Tilapia is the adopted stocking rate per ha, together with 2,500 carps. The average daily fish production in experimental ponds between 1961 and 1964 was 11.45 kg/ha in mono-culture and 14.5 kg/ha in mixed fish culture.

The other type of mixed fish culture (carp-grey mullet combination) proved successful in Israel because of the high value of the grey mullet. Carp-mullet mixed culture has not yet given the expected increase in total fish production. The proper quantitative relation for stocking these two species has yet to be worked out. In carp-mullet mixed culture grown-up mullet fingerlings, in their second year (30 to 70 g weight) are stocked in carp ponds at the rate of 500 to 800 fish per ha, and are marketed when weighing 400 to 700 g after 120 to 150 days.

Although mixed fish culture has spread to more than 50 percent of the fish farms (but not 50 percent of the area of fish ponds), it is still to be considered a new practice, in its first stages of development. Tables III and IV summarize the extent of the development of mixed fish culture in Israel.

3 COMPARISON OF DIFFERENT APPROACHES TO MIXED FISH CULTURE

Studying the character of mixed fish culture all over the world and trying to understand the essentials of the different approaches and techniques, one cannot avoid the recognition of the joint action of sociological, climatic and biological factors in building up the distinctive features of fish culture in the various regions of the world.

Table III

Number and percentage of fish farms cultivating Tilapia and grey mullet with carp in mixed culture in Israel in the years 1957-1964

	1957		1958		1959		1960		1961		1962		1963		1964	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Total Number of fish farms	95	100	92	100	92	100	93	100	95	100	94	100	96	100	96	100
Fish farms cultivating Tilapia	41	43.2	37	40.2	42	45.7	46	49.5	60	63.2	66	70.2	67	69.8	57	59.3
Fish farms cultivating mullet	12	12.6	31	33.7	34	37.0	24	25.8	25	26.3	32	34.0	37	38.5	45	46.8

Table IV

Marketing of pond fish during the years 1957-1964 in Israel (weight in metric tons)

Kind of fish	1957		1958		1959		1960		1961		1962		1963		1964	
	ton	%	ton	%	ton	%	ton	%	ton	%	ton	%	ton	%	ton	%
Carp	7420	98.50	7629	98.14	7657	97.03	8220	97.48	8527	96.08	8401	94.3	8982	92.2	9741	93.5
Tilapia	41	0.54	46	0.59	22	0.28	95	1.13	250	2.82	384	4.31	576	5.91	399	3.9
Mullet	68	0.90	99	1.27	212	2.69	117	1.39	98	1.10	124	1.39	182	1.87	267	2.6
Total	7529	100	7774	100	7891	100	8432	100	8875	100	8909	100	9740	100	10407	100

3.1 Far Eastern fish culture

The Far Eastern system of fish culture has developed in small family ponds in the plains of the big Chinese rivers - Yangtse and West river. The pond here is part of an ecological complex, the farmer's family erecting bath-house and latrine over the pond and the pigsty on the bank with its supply of pig faeces to manure the pond. During centuries the farmer taking care of his small pond, of several mow area (one mow = approximately 830 m^2) was able to select and adjust five or six fish species to grow together in the pond (Chen, 1934; Lin, 1951). This species association is highly adapted to utilize every possible food niche in the pond, as well as the supply of additional feed of plant and animal origin. The grass carp occupies an important position in this association; by using grass, vegetable waste and various aquatic plants as food and by converting this cheap material to food for other fish species, as half-digested excreta, they support various other food animals.

Age-long experience has established some rules for stocking the different fish species in the right proportion in order to obtain the best production. Regular thinning out of larger fish from the densely populated pond is important in this ecological complex, providing more space for the fish left in the pond to grow.

Thus Far Eastern fish ponds present an ecological complex in which the cheap available waste and refuse materials like grass, banana leaves, silk worm pupae, cow-dung, pig faeces, night soil and so on, are used by an association of fish species selected to use all available resources of the pond.

The essential feature of this system is the small-sized pond - the family pond, with an elaborate system of stocking and careful management, resulting in a high production. In Chinese ponds, the production averages 3,000 kg/ha, and in some areas of Central China it goes up to 7,500 kg/ha. This high fish production and low expenses attract the attention of fish culturists in other parts of the world to the far eastern experience and methods. Attempts have recently been made to introduce the Chinese carp to European fish ponds and lakes.

3.2 European fish culture

The European fish culture industry consists of big fish farms producing mainly carp. The big European fish ponds of a couple of hundred ha each could be constructed by the big landlords only, using cheap labour for construction. But the large area of each pond, promising a high fish production, made it difficult on the other hand, to manage and handle them intensively using man-power only. The demand for large-sized fish, especially for the Christmas holidays, and the climatic conditions of the temperate region, lengthened the growth period of fish in ponds to three summer seasons. This means that the fish farmer had to take care of the undersized fish during two winters. He had to direct all his efforts to find proper ways to enhance growth during summer and to prevent the fish perishing during compulsory hibernation in winter. The development of fish culture under these conditions was based on a natural food supply to avoid high expenses in using concentrates as additional feed.

These conditions hampered the development of the idea of mixed fish culture, which did not progress far beyond the recognition that it is worthwhile to add tench to the carp in ponds, to utilize the food animals left over by the sparse population of carp, and that Esox and Lucioperca may serve as "police" fish to control the undesirable small trash fish which enter the pond from the surroundings.

The distinctive features of the European fish culture industry are thus big fish ponds cropped once a year, growing carp for market size in a three-year rotation, mixed fish culture being a sideline only.

Some important changes are now taking place in fish culture in the U.S.S.R., and adjacent countries. The rotation time for marketable carp production is being shortened to two and even one year. In addition to carp, new fish species are introduced in order to utilize the plankton production in ponds. Those are *Coregonus peled* in the northern latitudes and *Hypophthalmichthys molitrix* in the southern areas. In waters covered with higher vegetation *Ctenopharyngodon idella* is added (Konradt, 1965; Gordon, 1965). By adopting the ecological approach, that different fish species with diversified ecological requirements will utilize the habitat more efficiently, the Russian fish culturists hope to increase and intensify their fish culture several times without the use of expensive and limited additional feed, thus avoiding clash with the needs of husbandry (Verigin, 1963).

3.3 Israeli fish culture

The Israeli fish culture industry is a recent development. In an age of intensive agricultural mechanization with a tendency to develop highly specialized mono-cultural farms, the Israeli fish farms have been developed into industrial enterprises. The work on the fish farms is mechanized to a large extent. Fish production is based on a half to one year rotation. Live carps are available on the market the whole year around. One of the distinctive features of the Israeli fish culture technique is the carefully planned schedule of pond stocking intended to assure continuous supply of live carp the whole year around. Careful control of the size of the carp population in ponds, aiming not to exceed the proper number per unit of area by wild spawning, is another feature of Israeli fish farming. The average daily production of 10.0 to 12.0 kg per ha serves as a yardstick to fish farmers for control of the fish ponds. This is done by weekly or bi-weekly control weighings of fish samples from each of the fattening ponds.

The very intensive process of fish farming in Israel makes the fish culturists cautious in ther approach to mixed fish culture. They fear that stocking additional fish species may decrease the high carp production in their intensively managed ponds. But the addition of new fish species into carp ponds is done not only with a view to complete utilization of the different ecological niches of the pond, it also takes into account the possible inter-specific competition and decrease of carp production as an outcome of it and the probable interference with the process of work in the pond, but as the growth rate of the different fish species varies, there is a possibility that the variously-sized fishes in the pond will affect the planned time table of "stocking, fattening and removal". The answer to this problem is a proper adjustment of the numbers of each of the species in the fish association.

A comparison of the mixed fish culture practices of China, Russia and Israel shows the existing common ideas on the subject in these countries - use of fish species with different feeding habits to utilize efficiently the natural food resources of the pond or lake. But whilst in China the idea and realization of mixed fish culture was worked out empirically through centuries of fish farming, in Russia and in Israel the introduction of mixed fish culture is a product of recent scientific and ecological analysis of pond productivity problems.

But the common ideas do not lead necessarily to the same practical solutions. These are dependent on local conditions. The Russians trying to increase fish production of several thousands of small lakes (in the latitude of Leningrad) inhabited by small, commercially not valuable fish species; poisoned totally the indigeneous fish populations, and replaced them by carp and *Coregonus peled* (Burmakin, 1965). The new fish association although artificially established, is growing on natural food resources only, the stocking rate being adjusted to natural food supply.

In Israel, the smaller pond area and the limited water supply imposed the necessity of intensive fish farming in order to meet the increasing demands for live fish. The fish pond complex is composed of the fish culturist with his continuous intervention in shaping the conditions in the pond, and the association of fish which is selected to utilize every possible requisite of growth. The proper interaction of the components of this ecological complex will secure the highest possible fish production. In various geographical regions different fish species will be involved in mixed fish culture, but the main problem in intensive fish culture, which requires a careful and detailed study, is the quantitative one - the proper relation of fish numbers of the different species in a pond.

4 EVALUATION OF THE EFFICIENCY OF MIXED FISH CULTURE

As already mentioned, in intensive carp farming, fish culturists are afraid to introduce additional fish species into their ponds in case these interfere with carp production. It is important therefore to work out a method of evaluation of the efficiency of mixed fish culture in increasing fish productivity of ponds.

Many data are available on carp mono-culture and mixed fish culture from commercial fish farms. There are some advantages in using these data from commercial ponds, sampled under field conditions, to describe a trend of development. But it will be dangerous to use them to make exact comparisons and evaluation of efficiency of one or another way of management, because there are many kinds and shades of management even in the same fish farm, and various ponds differ from each other, not only in shape and size but in the rate of stocking and general conditions. For exact studies and evaluation of the efficiency of one or the other method of fish culture to give management recommendations, the research station approach with experimental ponds will be required.

Two examples of evaluation of mixed carp-mullet and carp-tilapia farming are given in Tables VI and VII. In Table VI data on average daily carp productions in mono-culture and together with grey mullets are given. These data were collected during the years 1956 to 1959 from 76 commercial ponds in the fish farm Maagan-Michael (Israel).

Table VI

Frequency distribution of the average daily carp production (kg/ha) in commercial ponds of the fish farm Maagan-Michael in mono-culture (A) and mixed culture with *M. cephalus* (B) in the years 1956 to 1959

	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	No.of ponds	Average prod. kg/ha
A	-	-	-	-	1	2	4	5	6	5	4	-	1	1	-	2	30	13.8
B	1	2	1	3	12	7	8	4	4	4	-	-	-	-	-	-	46	10.7

As far as it is possible to compare these data on carp production from a commercial enterprise, it can be concluded that the presence of grey mullets tends to check carp growth. In this case the rate of stocking of the grey mullets was 800 to 1,200 fish per ha.

Table VII gives an evaluation of the efficiency of mixed culture of carp together with *Tilapia aurea*. All the data were obtained from experimental growth of carp and tilapia stocked at different densities. Data on carp production in mono-culture serves as control. Excluding the difference in stocking rates, the ponds received the same treatment during the years of experiment. It is assumed that the difference between the daily carp production in ponds with tilapia and the carp production in mono-culture is a result of competition between tilapia and carp. An index of the rate of competition can be estimated as follows:

$$C = \frac{a-b}{a},$$

C - index of competition
a - daily carp production in mono-culture
b - daily carp production in mixed culture

Table VII

The competitive relationship between carp and tilapia in ponds stocked at various density rates, expressed in units of daily fish production. (All data are averages of 3-7 ponds).

Year	Type of culture	Carp		Tilapia		Total daily prod. kg/ha	Competition index
		Stocking rate	daily prod.kg/ha	Stocking rate	daily prod.kg/ha		
1963	Mono-culture	5,500 1/	12.860	-	-	12.860	
	Mixed culture	5,500 1/	12.620	3,000	1,900	14,520	0.02
1964	Mono-culture	2,500	10.010	-	-	10,010	
	Mixed culture	2,500	10.230	3,000	3,380	13.610	(-)0.02 2/

1/ Combined carp population of fattening fish and fingerlings.

2/ The minus sign (-) of the competition index points to the fact that in some cases the influence of tilapia on carp was positive and its daily production exceeded that of the control.

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V/R-3

STOCK MANIPULATION AND OTHER BIOLOGICAL METHODS OF INCREASING PRODUCTION OF FISH THROUGH POND FISH CULTURE IN ASIA AND THE FAR EAST

by

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Abstract

This paper reviews the methods of stock manipulation and other biological procedures used to increase fish production in ponds in Asia and the Far East. It was noted that stocking rate is evaluated in number of fish or weight of stock or both, with due consideration of the age group of the stock. The main objective of stock manipulation is to take full advantage of the available pond space and its production of fish food in order to maximize production. Stocking of only one species or mono-culture is practised for a few species but increased use of stocking of a number of species in the same impoundment or multi-culture is more common. Milkfish culture in the Philippines and Taiwan is an example

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of mono-culture. The culture of various carp species in China and surrounding areas, the Indian major carps in India and Pakistan, and related cyprinids in Japan and Indonesia exemplify the multi-culture system.

Other biological methods used to increase production are summarized. Problems encountered in stock manipulation in ponds and possible lines of action for their solution are also discussed.

INTERVENTIONS SUR LES STOCKS ET AUTRES METHODES BIOLOGIQUES VISANT A ACCROITRE LA PRODUCTION DE POISSON DANS LES EXPLOITATIONS PISCICOLES D'ASIE ET D'EXTREME-ORIENT

Résumé

Cette communication passe en revue les méthodes d'intervention portant sur les stocks et autres procédés biologiques utilisés pour accroître la productivité du poisson dans les étangs piscicoles d'Asie et d'Extrême-Orient. Il est noté que le taux de peuplement peut s'évaluer soit en nombre de poissons, soit en poids total de la population, soit des deux façons, compte tenu du groupe d'âge du stock. Les interventions sur les stocks visent principalement à tirer pleinement parti de l'espace disponible et de la production de l'étang en aliments naturels afin d'obtenir la production maximale. Certaines espèces font l'objet de monoculture, c'est-à-dire qu'elles sont élevées seules, mais on a de plus en plus tendance à pratiquer la polyculture, c'est-à-dire l'élevage de diverses espèces dans le même plan d'eau. L'élevage des chanos aux Philippines et à Taïwan constitue un exemple de monoculture. L'élevage de diverses espèces de carpes en Chine et dans les régions avoisinantes, des principales carpes indiennes en Inde et au Pakistan et de cyprinidés d'espèces voisines au Japon et en Indonésie constituent autant d'exemples de systèmes dits de polyculture.

On trouvera dans la communication un résumé d'autres méthodes biologiques employées pour accroître la production. Les problèmes que posent les interventions sur les stocks en étangs et les diverses solutions possibles sont également examinés.

MANIPULACION DE LA POBLACION Y OTROS METODOS BIOLOGICOS PARA AUMENTAR LA PRODUCCION DE PESCADO MEDIANTE LA PISCICULTURA EN ESTANQUES EN ASIA Y EL LEJANO ORIENTE

Extracto

Se examinan en este trabjo los métodos de manipulación de la población y otros procedimientos biológicos utilizados para aumentar la producción de peces en estanques en Asia y el Lejano Oriente. Se debe hacer notar que la densidad de repoblación se evalúa en número de individuos o en peso de la población, o en ambas formas, teniendo presente el grupo de edad de la población. El objetivo principal de la manipulación de la población es aprovechar al máximo las disponibilidades de estanques y su producción de alimentos piscícolas con el fin de elevar al máximo la producción. Para algunas especies, la reproblación con una sola especie, o monocultivo, se practica pero cada vez es más corriente poblar con varias especies en las mismas aguas, o multicultura. El cultivo del bango (Chanos chanos) en las Filipinas y Taiwán es un ejemplo de monocultivo. El cultivo de varias especies de carpa en China y zonas adyacentes, las carpas "principales" de la India en la India y Pakistan y de ciprinidos conexos en el Japón e Indonesia, son un ejemplo de sistemas multiculturales.

Se resumen otros métodos biológicos utilizados para aumentar la producción. También se examinan los problemas con que se ha tropezado en la manipulación de poblaciones en estanques y las posibles formas de actuar para su solución.

1 INTRODUCTION

Pond fish culture is the method of fish production that lends itself most readily to management by man. Manipulation of the fish population stocked in water impoundments, a method of increasing the yield, as practised in Asia and the Far East is the subject matter of this paper. A review of other biological methods of increasing production in ponds is also attempted. The paper is based on information available from China, Japan, Hong Kong, Philippines, Indonesia, Singapore, Malaysia, Thailand, India and Pakistan, and on published literature, correspondence with scientists working in this field, and actual observations made during a tour of Southeast Asia in 1956.

"Stock manipulation" here means the methods employed to manage the introduced population, or populations, of the fishery resource, or resources, (fish, prawn, etc.) in a controlled body of water, such as ponds or other impoundments, until ready for harvest.

The kind of stock means the species used, while the amount of such stock is interpreted in terms of numbers or weights with due consideration to their age during the period of management.

2 STOCKING RATES AND STOCKING SYSTEMS

2.1 Stocking rates

The concept of stocking rate is variously interpreted in different countries in the region. In many places this rate is reckoned simply in number of stock per unit space of the habitat and with due consideration to the age group of such stock. In others, weight of stock per unit space is considered regardless of age groups of such stock. The first practice is convenient and popular and is generally accepted as a matter of course by many fish pond operators. The other types of practices are based on biological principles, considering the pond as an ecological unit. Various degrees of intergrading of these two stocking concepts may be encountered in the region.

2.2 Mono-culture stocking

The stocking of fish cultural waters with just one particular species or mono-culture stocking is fast becoming a practice of the past. It is now practised only in well established fish cultural industries in certain countries or with highly desirable species in certain places. *Chanos* and eel culture are good examples of this practice in some Asian and Far Eastern countries. There may also be a future for both marine prawn (*Penaeus*) mono-culture or fresh-water prawn (*Macrobrachium*) culture because of the high demand for these species in many places in the region as well as the outside market. It has been reported also that the culture of other highly desirable marine species has been started in marine ponds previously used as salt-water reservoirs for salt works in Japan.

2.3 Multi-culture stocking

In most Asian and Far Eastern countries today the rearing in the same impoundment of more than one species, multi-culture stocking, has become a general practice. This is founded on a sound biological basis which calls for the maximum use of the pond space and the foods available by using different species of fish with varying behaviour and feeding habits. Multi-culture of Chinese carps in China, Hong Kong, Malaysia and Thailand; Indian major carps in India and Pakistan; and common carp and other cyprinids in Japan and Indonesia, are examples of this development.

3 STOCK MANIPULATION

3.1 Stock manipulation in mono-culture stocking

Even when only one species is cultivated, stock manipulation can be used to increase the production of fish from ponds. Clever stock manipulation practices under mono-culture are best exemplified with Chanos culture in the region.

3.1.1 Stock manipulation in Philippine Chanos ponds

In the Philippines there is a well developed Chanos nursery pond industry. This is a segment of the Chanos culture industry specialized in rearing milkfish fry to the fingerling stage, then stunting and maintaining them in good health to provide continuing stock for fish ponds during periods of the year when no fry are available from the marine spawning grounds of the milkfish.

In the big rearing pond areas where milkfish are raised to marketable sizes, fish of the same age group are generally stocked. But the frequency in which harvests of marketable fish can be made from these ponds will greatly determine the amount of profit from them. Increased frequency of cropping has recently been promoted by making use of a series of transition ponds which can provide stock of increasingly larger sizes than fingerlings of five to nine centimeters in length, such as post-fingerlings and premarketable sizes of 10 to 25 centimeters in length. By using these larger fish to stock the big rearing ponds, the interval between harvests can be reduced to 15 to 45 days, instead of the usual 90 to 180 days, and the natural food present in such ponds is usually not fully consumed after each cropping period. Recovery of the natural growth of the food to receive the next stocking of fish will then be more rapid. It is estimated that by this system production has been raised to about 800 to 1,500 kg/ha/year instead of the usual 400 to 600 kg.

3.1.2 Stock manipulation in Chanos ponds in Taiwan, China

Skilful manipulation of the fish stock in Chanos ponds of Taiwan has resulted in the comparatively very high production of fish from these ponds. Putting into use most possible areas available for this purpose, totalling 18,000 ha, this country has at present a level of production averaging about 2,000 kg/ha/year. The stock manipulation techniques that have been developed in Taiwanese milkfish ponds are based on the use of bottom crust micro-flora as the most suitable and easily replenishable natural food, and the stocking of milkfish seedlings of graded sizes which can make continuous and full use of the yield of natural growth of the rapidly self-replenishing food supply. The fish populations in these ponds are, however, carefully watched and cropped systematically but replaced with fish of lesser weight, so that a series of crops of fish of varying size groups are available for planned periodic removal from the ponds.

Table I summarizes a typical plan for stock manipulation in Chanos ponds in Taiwan. This table shows that the initial stocking of the ponds about April each year involves fish seedlings of three size groups, that would total from 100 to 200 kg/ha upon stocking. It has been found that a hectare of pond area is capable of yielding some 70 to 120 kg of fish food each day, which if not utilized would only perish naturally. Therefore the initial fish stock should be able to utilize to the maximum this food producing capacity of the pond, with the result that the fish will grow rapidly. This necessitates early harvest, or as soon as the total weight of the pond fish population approaches 500 kg/ha, to avoid loss of the natural food growth. Therefore initial harvest using gill net seines is usually started as early as two weeks to one month after the initial stocking, and regular harvests at equal intervals (about two weeks apart) are usually made throughout the entire crop period of the year, which extends from April to October. From 10 to 13 harvests can be made during this time. Replenishment of stock with new batch of fry is done to balance withdrawals during these periodic harvests. In spite of the short culture period of only seven months of the year, the Taiwanese fish culturists are at present reported to be producing on the average about two tons/ha, due to the skilful stock manipulation of these ponds.

Table I

Stock manipulation in Chanos fish ponds in Taiwan, (Based on personal communication of Mr Yun-An Tang, UN/FAO Inland Fisheries Biologist in the Philippines)

Stocking no.	Period of stocking	Age stage of stock	Av. no. of fish per kg stock	No. stocked per ha	Total of stock on stocking (kg/ha)	No. of days when stock harvestable after stocking	No. of harvests for each stock	Period of harvest for each stock	Av. no. of fish per kg on harvest	Per-cent survival of stock	Production (kg/ha)
I	Early April	(1) Large yearling	15-20	1500	75-100	45-70	2	Mid-May to, early June	3.5	95	400
		(2) Small yearling	30-50	1500	30-50	70-90	2	Early to end of June	3.5	95	400
		(3) Post-fry	200-300	3000	10-15	100-140	3	Early July to mid-August	4.5	95	500
II	End of April or early May	Fry	16 mm long each 0.08 g	3000	-	120-150	3	End of August through September	5	85	500
III	End of May or early June	Fry	16 mm long each 0.08 g	4000	-	120-150 Partly for next year stock	3	Early August to end of October	5	85	200
IV	End of June or early July	Fry	16 mm long each 0.08 g	4000	-	For next year's stock	-	-	-	-	-
Total	-	-	-	-	-	-	13	-	-	-	2000

3.2 Stock manipulation in multi-culture stocking

Based on the principle of utilizing to the maximum the pond water space and the natural fish food it provides, several alternative multi-culture stocking practices have been developed in different places in Asia and the Far East. The local practices developed have been partly a result of the kinds of fish stock readily available and of the market demand for the different species.

3.2.1 Stock manipulation of Chinese carps and related species in fish ponds in China and other countries using these species

Several cyprinid species indigeneous to the Chinese mainland thrive well both in natural fresh waters and controlled impoundments. These are: silver carp, Hypophthalmichthys molitrix; bighead, Aristichthys nobilis; grass carp, Ctenopharyngodon idella; black carp, Mylopharyngodon piceus; mud carp, Cirrhina molitorella; bream, Parabramis pekinensis; and common carp, Cyprinus carpio. None of these species are known to be strongly carnivorous or cannibalistic and they vary in their behaviour and food preferences. They are either omnivorous, herbivorous or plankton or benthos feeders; or they may be surface-loving, column swimming or bottom-loving in habit, hence if properly combined a combination may result in the maximum use of an impoundment.

Since very early times, the Chinese people have developed suitable combinations for these different species. The principles of compatability of the combined species and maximum utility of environmental products and space are the main guiding factors for the stocking combinations developed in different regions of China and surrounding areas. Other considerations which may modify stocking combinations in these different areas include local availability of the fish seedlings, adaptability of these species to local climatic conditions and market demand for specific kinds of fish. For example, fish ponds in Kiangsu Province, China, are reported as combining stock of black carp, grass carp, silver carp, bighead, common carp and sometimes bream. The functions of the species used in this combination are said to be (i) black carp to feed on snails and other molluscs at the pond bottom, (ii) grass carp to feed on coarse vegetable matter, (iii) silver carp to feed on planktonic organisms, (iv) bighead to feed on macroplankton, (v) common carp to be an omnivorous scavenger, and (vi) bream to reinforce the omnivore group. The use of mud carp which is known to feed on worms and organic matter at the bottom is not possible in this region of extreme cold weather at certain seasons of the year. Details of numbers and sizes of fish stocked are given by Hora and Pillay (1962); in ponds averaging 2.5 m in depth all six species may be stocked together totalling 9,500 fish per hectare, the fish being stocked when between 120 to 350 mm long. In deeper ponds (3 to 7 m) yearlings, weighing 200 to 500 g are stocked up to 12,200 fish/ha.

Reduction in the number of species used has been reported as practised at Chekiang Province, China, as exemplified in the practices noted in the cities of Tinghai and Shoashing. Here, black carp, silver carp, bighead and common carp are used. Table II enumerates the relative number used for these species, for a three-year culture period. Mortality rates are said to be low, 10 percent during the first two years and negligible during the third year. Large-sized quality fish are produced ranging from 750 g of common carp to as much as 5 kg of black carp.

Table II

Stocking combinations practised in Chekiang Province,
China, specially in the cities of Tinghai and Shoashing
(After Hora and Pillay, 1962)

Species	First year		Second year		Third year		Average weight of fish on harvest (g)
	Initial weight (g)	No. of fingerling per ha (age 3-9 months)	Initial weight (g)	No. per ha (age 15-20 months)	Initial weight (g)	No. per ha	
Black carp	35	6,000	500	1,300	2,750	240	5,000
Silver carp	40	400	600	1,000	600	400	1,500
Big head	40	400	600	80	600	300	2,000
Common carp	30	400	350	50	350	200	750
Totals		7,200		1,530		1,140	

Further modification in stocking combinations has been noted along the West River region of South China and Tonkin of North Vietnam. Here the warmer climate, depth of pond, nature of water supply, kind of feeds available, and basic pond fertility are considered in determining the stocking rates and combinations used. It is noted also that emphasis is given to the mud carp which is a subtropical species rather than the cold-resistant black carp used farther north. The stocking combinations used in this region are given by Hora and Pillay (1962, p. 128) and vary according to the depth of the pond.

Hora and Pillay (1962, p. 129) also give the stocking combinations used in Hong Kong. A special feature of the practice in this area includes the heavy use of the grey mullet, Mugil cephalus, to supplement the various cyprinid species and, as the climate is warmer, black and mud carps are less used. Slightly brackish water is used in the ponds and since such ponds are heavily stocked (with between 26,000 - 34,000 fish/ha, stocked when between 2.5 - 7.5 cm long) regular cropping is practised as needed to thin the stock.

Thailand, Malaysia and Singapore have to some extent adopted the culture of the Chinese grass, bighead, and silver carps with the common carp in their fish ponds as practised in China. The methods used in these places are, however, modified by the availability of fry since they have to be imported, the more or less tropical climate, the amount and kind of feeds available and the market demand for the different species. Species that are more adapted to colder waters, like the mud and black carps are not usually used, while the vegetation feeding grass carp is well favoured. The grass carp, bighead, silver carp and common carp are the principal species used and in varying combinations. Details of stocking combinations used in Malaysia, Thailand and Singapore are given by Hora and Pillay (1962), between 650 and 1,750 fish/ha are stocked of fish between 30 and 600 g weight.

The Singapore method of stock manipulation seems to be an improvement of the practice in Malaysia and Thailand. This consists of extending the rearing of grass carp, bighead and silver carp to eight months instead of three before transferring to the fattening ponds for another six months which results in a bigger and better quality harvest.

Practical and clever modifications in fish stocking practice with the use of Chinese carps and other suitable species have been developed in Taiwan (Table III).
As in Hong Kong, the mullet is combined with the cyprinid species of bighead, silver,

grass and common carps and in addition milkfish, *Chanos chanos*; tilapia, *Tilapia mossambica*; and sea perch, *Lateolabrax japonicus* are also used. As previously used in combination in other regions of China and neighbouring areas the Chinese carps are complementary species with silver carp as plankton feeder, bighead, as macroplankton feeder, grass carp as coarse vegetation consumer and common carp as bottom scavenger. The mullet and milkfish are consumers of bottom algae and tilapia is a fast reproducing omnivore that needs to be cropped daily to every three days during the culture period. The sea perch is a carnivore used in limited numbers to control small forage species, like extraneous minnows and excess small tilapia. A typical stocking procedure giving the age group of stock, stocking rate, period of stocking, period of harvest and duration of culture and expected yield per hectare fish pond per year is shown in Table III. This table shows that well managed ponds under this system may yield from 5,000 to 7,000 kg/ha/year consisting of tilapia (2,000-3,000 kg), carps (2,500 - 3,500 kg), mullet (1,000 kg), milkfish (300 - 400 kg) and perch (50 - 60 kg). This shows that bringing in tilapia, mullet and milkfish with the Chinese carp combination has greatly increased the overall production in these ponds.

Table III

Multi-culture stocking practice and results in fresh-water fish ponds in Taiwan,
(Yun-An Tang, personal communication)

Species	Age group (length in cm)	Number stocked/ha	Period of stocking	Period of harvest and duration of culture	Expected production kg/ha/year
Silver carp	5 - 8	2000 - 3000	February	January (1 year)	1500
Bighead	8 - 10	100 - 300	February	January (1 year)	300
Grass carp	8 - 10	100 - 300	February	January (1 year)	150 - 200
Common carp	3 or 8 - 10	1000 - 1500 or 500 - 700	February or May to July	January (7 months to 1 year)	300 - 500
Mullet	3	3000 - 4000	February	January (1 year)	1000
Milkfish	8 - 10	1000 - 2000	April	August	300 - 400
Tilapia	5 - 8	3000 - 5000	April to May	Daily to every 3 days selective harvest from June	2000 - 3000
Sea perch *	8 - 10	30 - 50	June	January (8 months)	50 - 60
Total	-	9730 -16150	-	-	5000 - 6960

* *Lateolabrax japonicus*

3.2.2 Stock manipulation in Japanese fish ponds

Nakamura, *et al.*, (1954) reported the existence of farm ponds in Japan used for irrigation and fish ponds in the rice field plains. These are in addition to small unit ponds used for eels, ayu or sweetfish (*Plecoglossus altivelis*) and carps elsewhere in that country. The above-named Japanese workers reported that in the farm ponds the basic species combination used include the common carp, crucian carp (*Carassius* species), and shrimp (*Leander paucidens*), with the fish as the major species. The common carp is an omnivorous bottom scavenger while the crucian carp is a plankton feeder. Besides the ordinary crucian carp (*Carassius carassius*), improved varieties of this species like the *gengoro buna* and goldfish (*Carassius auratus*) may be used in combination with the common carp. No special niche in the pond ecology seems to be attributed to the shrimp but it is desirable and income-giving for the fish farmer. Increased production and improved utilization of natural foods in the pond were attained with the introduction of the Chinese grass carp. Chinese bighead and silver carp have also recently been introduced. Other desirable species may also be included in the pond stock, including the eel, *Anguilla japonica*, and pond smelt, *Hypomesus olidus*. Table IV shows three typical stocking combinations and the relative expected productions in Japanese farm ponds.

Table IV

Species combination in Japanese farm ponds and results
(Derived from Nakamura *et al.*, 1954)

Species combination	Stocking			Cropping		
	Average weight of seedfish (g)	Number stocked/ha	Total weight stocked (kg/ha)	% survival of stock on harvest	Average weight of stock on harvest (g)	Total production (kg/ha)
I 1. Common carp *	41	172	7	79	734	88
2. Crucian carp **	7	218	11	76	-	139
3. Shrimp	-	-	3.7	-	-	45
Range of total production for this stocking combination is 136 to 450 kg/ha/year					Total =	262
II 1. Common carp *	72	134	6.4	77	527	46
2. Crucian carp **	-	-	9.3	100	-	143
3. Shrimp	-	-	-	-	-	44
4. Grass carp	3,066	6	28	100	8,000	64
Range of total production for this stocking combination is 185 to 325 kg/ha/year					Total =	297
III 1. Common carp *	36	300	11	47	330	46
2. Crucian carp **	30	220	6.4	-	-	180
3. Shrimp	-	-	-	-	-	3.6
4. Grass carp	730	29	21	82	3,100	73
5. Eel	-	-	-	-	167	2.2
6. Pond smelt	-	-	-	-	-	4.2
					Total =	309

* Young (20 to 100 g in weight) or adults (1 to 2.5 kg) of common carp may be used, with the number of stock adjusted per unit area

** *Gengoro buna* variety or goldfish alone or in combination may also be used for crucian carp. All are included under *Carassius auratus* in Nakamura *et al.*, 1954

3.2.3 Stock manipulation in ponds using the Indian major carps in India and Pakistan

The remarkable fresh-water species of fish in the region of India and Pakistan consist of cyprinids known as Indian major carps. Among several species the kinds selected and most commonly used for pond fish culture are catla, Catla catla; rohu, Labeo rohita; mrigal, Cirrhina mrigala; and calbasu, Labeo calbasu. Like the Chinese carps, these species also have suitable and complementary behaviour and feeding habits. The catla feeds on the surface strata; mrigal is a bottom feeder; rohu is a column feeder; and calbasu if added is a bottom feeder on molluscs. The stocking combinations using the Indian major carps as developed in India and Pakistan are shown in Table V a and b; productions of 250 to 1,500 kg/ha/year may be attained.

Table V

Stocking combinations developed for the Indian major carps in India and Pakistan

a. General stocking combination developed (After Hora and Pillay, 1962)

Species	% of stock recommended		Stock per hectare of 8-13 cm long fish	
	I	II	I	II
Catla	30	30	1,875	1,875
Rohu	60	50	3,750	3,125
Mrigal	10	10	625	625
Calbasu	-	10	-	625
Total	-	-	6,250	6,250

b. Stocking combinations taking into consideration ecological condition of pond (Partly after Ahmad, 1952)

Species	Water condition *														
	I			II			III			IV			V		
	%	Stock no.		%	Stock no.		%	Stock no.		%	Stock no.		%	Stock no.	
cm		10-13	15		10-13	15		10-13	15		10-13	15		10-13	15
Catla	50	300	200	30	132	88	40	128	84	30	66	44	equal	36	24
Rohu	30	180	120	35	154	103	30	96	63	35	77	51		36	24
Mrigal and Calbasu	20	120	80	35	154	103	30	96	63	25	77	51		36	24
Totals		600	400		440	294		320	210		220	146		108	72
Av. annual production per bigha/maunds		6			4			3			2			1	
Equivalent in kg/ha		1656			1104			828			552			276	

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Water

* Condition I - Greenish water with permanent plankton bloom
II - Clear with higher aquatic plants under control
III - Brownish with good amount of zooplankton and less amount of phytoplankton
IV - Clear, neither abundance of plankton nor higher plants
V - Muddy almost without aquatic vegetation

NOTE : Annual growth of species observed: catla - 1 seer; rohu - 3/4 seer; mrigal and calbasu - ½ seer. (one seer = 1 kg).
Three bighas equivalent to one acre. (one bigha = 0.1350 ha).
Maund is equivalent to 37.324 kg.
1 maund/bigha = 276.4 kg/ha.

3.2.4 Stock manipulation of various fresh-water species in Indonesian fish ponds

The fish ponds of Indonesia started at a very early period and have the characteristic feature of being cropped frequently with little regard to the size of fish cropped. People here are less concerned with the size of fish. Therefore, the stocking of Indonesian fish ponds does not depend very much on the number of fish stocked nor the aggregate weight of the stocking material but on the relative proportions of the desirable species planted per unit area of the ponds. Table VI shows the percentage composition of compatible combinations of indigenous and introduced species in fish ponds in Indonesia. The native species include tambakan or kissing gourami, Helostoma temmincki; tawes, Puntius javanicus; nilem, Osteochilus hasselti; and gourami, Osphronemus goramy. The introduced species that are now established are common carp and tilapia, which fulfil in Indonesian fish ponds the same roles that they do in fish ponds of other countries, that is common carp is an omnivorous bottom scavenger and tilapia is an all-round omnivore. The tambakan is a strong plankton feeder while the tawes is the consumer of coarse pond vegetation, playing the role of the grass carp in other countries, while gourami is a herbivore utilizing the softer vegetable materials along the pond margins; nilem eat plankton, periphyton and soft or decayed vegetation. Three kinds of typical combinations are shown in Table VI. The first makes use of the tilapia and common carp combination. The second is based on tilapia as the major species, while the third utilizes tambakan and tawes as major species. Since the cropping is generally fractional and continuous, it is difficult to assess the production per unit area and time in these ponds, but their production must be high since they have been found to be the ideal combinations giving best results from these tropical ponds.

Table VI

Stocking combinations used in Indonesian ponds

a. Common carp and tilapia combination

Species	Percent in stock
Common carp	80
Tilapia	20

Table VI (contd.)

b. Based on tilapia as major species

Species	Percent in stock composition	
	I	II
Tilapia	35	40
Common carp	30	10
Tambakan	-	20
Tawes	-	15
Nilem	20	15
Gourami	15	-

c. Based on tambakan and tawes as major species

Species	Percent in stock composition	
	In stagnant ponds	In ponds with water inflow
Tambakan	50	37.5
Tawes	10	37.5
Common carp	20	12.5
Nilem	20	12.5

3.3 Other biological methods of increasing fish pond production

Among several methods that might be mentioned here the following are particularly impressive: (i) the cropping of relatively small fish rather than waiting for the stock to grow to bigger sizes; (ii) adoption of a balanced forage-carnivore stock combination; (iii) control of the reproduction of very prolific cultivated stock, and (iv) heavy stocking in running water accompanied by intensive feeding.

Although there are no actual figures to prove that harvesting smaller sizes of the species under cultivation yields higher production than cropping bigger ones, it is common biological knowledge that as the fish grows, the demand for maintenance is proportionately increased and the allowance for growth thereby reduced. It follows that production of smaller sizes within the species can be more economical in terms of aggregate quantity produced, than trying to produce bigger sizes before harvest. The Indonesian practice of cropping relatively smaller-sized fish is probably incidentally premised on this principle. It is a practical method limited only by the demands of the consumers for certain desirable sizes of these fishes.

The forage-carnivore combination in fish culture work is a well-established practice, especially in countries where sport fishing is the main objective in fish culture. In the United States, the blue gill bream-black bass combination is well-known in fish culture. In Asia and the Far East, attempts are being made to make use of the snakehead Ophicephalus as the carnivore and tilapia as the forage species. Experiments along this line with a fair degree of success have recently been reported from Thailand. Further experiments are needed to establish this method on a firm basis.

One of the handicaps of culture for certain species is the extremely rapid rate of reproduction of the stock right in the ponds where the fish are cultivated. In Tilapia mossambica this problem of rapid reproduction is serious and has attracted the attention of fish culturists. Researches conducted at the Fish Culture Research Institute at Batu Berendam, Malaysia, revealed that this problem may be solved by crossing the female of the species with male of T. hornorum from Zanzibar as the offspring of this mating were 100 percent males. Such fish can be used for mono-sex stocking to eliminate the excessive reproduction encountered in these tilapia. This is a research result of very encouraging significance, and it is hoped that the attendant problems of the mechanics of putting this into practice can be solved as rapidly as possible, so that this can be adopted as a standard fish cultural practice.

The results obtained with heavy stocking of common carp species in running water impoundments accompanied by intensive feeding, as practised in Japan, are phenomenal in terms of production per unit time and space. With feeding in stagnant ponds, Hora and Pillay (1962) reported that with the use of common carp, Japanese ponds can produce from 2,500 to 4,500 kg/ha/year, but with adequate water supply, or where constant flow of water can be maintained, production up to 5,500 kg can be attained. When this culture is further shifted to running water impoundments constructed as diversions from streams or irrigation canals and heavily stocked with as much as 280,000 to 850,000 fish/ha (of 56 to 150 g each) it is reported that with 10 to 30 percent mortality, yields of up to 700,000 fish of 250 g average weight, the equivalent to an aggregate weight of 17,500 tons/ha/year, can be produced. Of course the anomally of this computation is the fact that these running water ponds are usually of small sizes, seldom bigger than 100 m^2. However, it shows that if the danger of oxygen-deficiency is removed and provision for the rapid disposal of metabolites is taken care of, heavy stocking with intensive feeding can result in a maximum attainable production per space and time as shown in the above cited Japanese practice.

4 PROBLEMS OF STOCK MANIPULATION IN FISH PONDS

The use of stock manipulation to increase fish pond yields is at present hampered by:

i Lack of, or inadequate supplies of suitable fry for stocking in many areas of the region. This is particularly true with Chinese and Indian carps outside of the countries where they are endemic;

ii The need for more information on feeding behaviour and preferences and changes in this with age (size) of fish;

iii The need for better techniques of production of suitable natural fish foods;

iv The need for data on the most profitable sizes at which to crop the different species, based on the relative amounts of consumed food used for growth and maintenance;

v The development, if possible, of more efficient stocking combinations using species from different places;

vi The dangers of both over-enthusiastic and ambitious introductions of new fish to a country, and the over-cautious prohibition of such introductions. Examples of bitter lessons from indiscriminate introductions are known but introductions on a rational and well-studied basis have to be encouraged.

5 RECOMMENDATIONS

The following developments could help to promote greater production through stock manipulation:

i The organization of an international or regional fry production-distribution system to overcome barriers to supply and distribution among countries of the region.

ii The establishment of an international fish culture research and training centre, as well as local national fish culture centres as counterpart institutions in each country, wherever possible.

iii Organization of fish culture research activities at least within the region to effect wider coverage of research by avoiding duplication, co-ordinate checking research results where necessary, and tackling problems by a system of appropriate priorities.

iv Devising a more effective system of disseminating methods, practices, and information through facilitated exchange of literature, promotion of exchange visits of technical men, scientists, fish culture workers, etc.

v Formulation of an international system and understanding of quarantining and prophylaxis of distributed fish among countries to prevent outbreaks and transfers of fish diseases and parasites as the joint responsibility of sender and recipient countries.

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METHODES BIOLOGIQUES D'ACCROISSEMENT DE LA PRODUCTION PISCICOLE (EUROPE ET AFRIQUE)

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Résumé

En matière de production piscicole, il faut distinguer les productions quantitative, qualitative et économique. Il existe de nombreuses méthodes biologiques d'augmenter la production.

En premier lieu, elle peut être considérablement influencée par le choix des espèces. Si l'on vise la production quantitative, il y a lieu de rechercher des espèces à chaîne alimentaire courte.

Le calcul de la mise en charge est important. Celle-ci se détermine de manières différentes selon que les poissons ne se reproduisent pas ou se reproduisent durant la période d'élevage. La mise en charge est en liaison très étroite avec la productivité de l'étang, laquelle englobe la productivité naturelle, celle de la fumure et celle due à l'alimentation artificielle des poissons. La productivité varie en fonction de nombreux facteurs, par exemple le nombre et l'âge des poissons.

La température influence la croissance du poisson. Il existe certaines possibilités de l'adapter aux nécessités de l'élevage.

Le mélange des espèces et des classes d'âge peut augmenter la production. Il existe de nombreuses formules de mélange, notamment entre non-voraces seuls ou bien avec voraces. Pour augmenter la production on peut réaliser plusieurs élevages successifs au cours d'une année, les modalités varient selon les climats. On peut aussi réaliser plusieurs productions simultanées, animales et végétales, dans l'étang, par exemple par la rizipisciculture et l'élevage de canards. Dans certains cas, les pêches intermédiaires peuvent augmenter sensiblement la production quantitative.

Plusieurs techniques spéciales, par exemple l'élevage des prédominants, la monosexculture et l'élevage d'hybrides peuvent aussi augmenter la production.

BIOLOGICAL METHODS OF INCREASING FISH CULTURE PRODUCTION (EUROPE AND AFRICA)

Abstract

Three aspects of production should be distinguished - quantitative, qualitative and economic. There are many biological methods of increasing production.

First, it may be improved considerably by the selection of the right species. If the aim is quantity, fish species with a short food chain should be used.

The correct stocking rate, itself dependent on whether or not the fish breed during the rearing period, must be calculated. The stocking rate is closely bound with pond productivity, viz: that due to a combination of natural conditions, fertilization and artificial feeding. It varies in relation to many factors, such as the number and age of the fish.

Temperature affects fish growth and there are ways of regulating it to fish culture requirements.

Production can be augmented by stocking the pond with several different species and age classes. There are many ways of doing this, in particular by using non-predatory species only or else these species together with predators. Another means of increasing production is to raise several successive batches in the course of a year by methods suited to the climate. Also several crops, both animal and plant, can be obtained simultaneously, for example, by rearing fish and ducks in rice fields. In some cases intermediate fishing will greatly increase the yield.

Several special techniques, for instance, rearing dominant species, keeping one sex only and breeding hybrids may also improve production.

V/R-4

METODOS BIOLOGICOS PARA AUMENTAR LA PRODUCCION PISCICOLA (EUROPA Y AFRICA)

Extracto

En materia de producción piscícola, es preciso distinguir entre las producciones de tipo cuantitativo, cualitativo y económico. Para aumentar la producción existen numerosos métodos biológicos.

En primer lugar, la elección de especies puede influir considerablemente en la producción. Si se considera la producción de tipo cuantitativo, es necesario buscar especies de cadena alimentaria corta.

Es importante calcular el número de peces para reproducción, que se determina de diferentes modos, según que éstos no se reproduzcan durante el período de la cría. El número de peces para reproducción se halla en relación muy estrecha con la productividad del estanque, la cual engloba la productividad natural, la del abonado y la debida a la alimentación artificial de los peces. La productividad varía en función de numerosos factores, por ejemplo el número y edad de los peces.

La temperatura influye en el crecimiento de los peces. Existen ciertas posibilidades de adaptarla a las necesidades de la cría.

La mezcla de especies y de clases de edad puede aumentar la producción. Hay numerosas fórmulas de mezcla, especialmente entre no voraces solos o con especies voraces. Para aumentar la producción se pueden realizar varias crías sucesivas durante el curso de un año, variando las modalidades según los climas. También se pueden realizar en el estanque varias produccíónes simultáneas animales y vegetales, por ejemplo mediante la piscicultura en arrozales y la cría de patos. En ciertos casos, las pescas intermedias pueden aumentar sensiblemente la producción cuantitativa. Varias técnicas especiales, por ejemplo la cría de especies predominantes, la mono-sexocultura y la cría de híbridos pueden aumentar también la producción.

1 NOTIONS INTRODUCTIVES

1.1 Conceptions diverses de la production en pisciculture

La pisciculture a pour objet l'élevage rationnel des poissons. Elle tend non seulement à leur multiplication quantitative, mais encore à l'amélioration qualitative des produits (Huet, 1960).

Le but principal de la pisciculture de production de poisson de consommation en étang est, généralement, la production d'une quantité aussi grande que possible de poisson comestible de grande valeur commerciale (Schäperclaus, 1961) et ce dans des délais aussi courts que possible.

La conception de la production piscicole diffère cependant, et parfois très fortement, selon l'objectif visé. On peut principalement parler de production quantitative, de production qualitative et de production économique.

La production quantitative vise à produire une quantité aussi grande que possible de poisson comestible. Son but essentiel n'est pas de produire du poisson de haute qualité, ce qui correspond souvent à du poisson calibré. La production quantitative est celle qui, en poids, donne les productions les plus élevées. Elle est notamment atteinte en Afrique par l'élevage des tilapias par la méthode des classes d'âge mélangées.

La production qualitative cherche à produire une quantité aussi grande que possible de poisson comestible de haute valeur commerciale. La production en poids n'est pas maximum, mais les poissons, généralement de poids et de tailles uniformes pour une espèce donnée, ont une grande valeur commerciale. Ce type de pisciculture correspond, en Afrique, à l'élevage des tilapias par classes d'âge séparées. Selon Bard (1962a) cette méthode peut donner une production en poids égale aux 2/3 de la production quantitative obtenue par le mélange des classes d'âge.

La production économique tend à produire une quantité aussi grande que possible de poisson de haute valeur commerciale. Le poisson produit est soit du poisson de consommation de haute valeur, par exemple le gouramy en Extrême-Orient, ou du poisson de repeuplement, non comestible, mais ayant une valeur marchande très élevée. L'unité de production n'est pas nécessairement le poids mais plutôt la pièce. C'est le cas de la production de brochetons ou de sandres de un été dans les étangs à carpes d'engraissement (Steffens, 1960). Généralement en ce cas la production quantitative, exprimée en poids, n'est pas très élevée.

1.2 Moyens d'augmenter la production

Que la production soit quantitative, qualitative ou économique, il existe de nombreux moyens de l'augmenter. Ces moyens sont biologiques ou non biologiques. Avant de traiter des moyens biologiques retenus dans la présente étude, il est donné un bref rappel des méthodes diverses susceptibles d'augmenter la production.

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1.2.1 Méthodes non biologiques d'accroissement de la production

Elles sont nombreuses et la plupart d'entre elles sont discutées durant le symposium de pisciculture. Elles concernent :

1.2.1.1 L'entretien et l'amélioration des étangs

En dehors de l'entretien des digues, de leurs berges et des ouvrages d'art des étangs, l'entretien et l'amélioration de ces pièces d'eau vise principalement:

(i) La lutte contre la végétation aquatique envahissante. Elle se pratique principalement par des moyens mécaniques (faucardage) ou par des moyens chimiques. Ces problèmes figurent au point 4 du symposium.

(ii) L'amélioration et la restauration du fond des étangs. Les principales méthodes utilisées à cette fin ont pour objet : la mise à sec (simple et laissant le sol à nu ou combinée avec une culture agricole = évolage) et la désinfection périodiques du fond des étangs; le travail du sol des étangs par ameublissement superficiel ou par labour plus ou moins profond; le curage des étangs trop fortement envahis par la végétation verticale ou par les atterrissements. Le point 1 du symposium concerne ce problème.

L'entretien et l'amélioration des étangs constituent des moyens nécessaires pour le maintien de la productivité naturelle de ces pièces d'eau et très utiles pour l'amélioration de cette productivité.

1.2.1.2 Le chaulage et la fumure des étangs

L'usage des amendements et des engrais, traité au point 2 du symposium, fournit un moyen à la fois simple et économique d'augmenter la production des étangs. Son emploi doit être généralisé. Le chaulage a une action très variée et favorable à l'état sanitaire de l'étang et des poissons et aussi aux facteurs biologiques de la production. La fumure augmente et accélère la production de la nourriture naturelle disponible dans les étangs. De ce fait, la mise en charge de ceux-ci et leur production sont sérieusement augmentées, souvent dans une proportion dépassant 50 pour cent de la production naturelle de l'étang non fumé.

1.2.1.3 Nourrissage des poissons en pisciculture

Le nourrissage ou distribution d'aliments, dits artificiels, est l'un des principaux moyens d'augmenter la production en pisciculture. Il en est discuté au point 3 du symposium.

L'importance et l'intensité du nourrissage varient selon les types de pisciculture pratiqués. Dans certains types de pisciculture, notamment en salmoniculture, l'alimentation artificielle peut former la base exclusive de la nourriture du poisson d'élevage qui devient ainsi, à ce point de vue, indépendant du milieu où se pratique l'élevage, lequel peut alors donner des productions dépassant 100 tonnes à l'hectare (Schäperclaus, 1963b). En carpiculture, la nourriture naturelle, éventuellement augmentée par l'action de la fumure, doit toujours représenter une part importante de la ration alimentaire du poisson. En utilisant à la fois la fumure et le nourrissage, on peut arriver, en carpiculture, à porter la production globale jusqu'au sextuple de la production naturelle initiale. Par contre, il n'est pratiquement pas possible de nourrir artificiellement certaines espèces de poissons; c'est par exemple le cas du brochet (Esox lucius).

1.2.1.4 Mesures techniques et sanitaires d'ordre général

En dehors des mesures précitées et avant même de passer à l'application de celles-ci, il va de soi qu'il est indispensable d'utiliser les mesures techniques et sanitaires générales qui conditionnent la réalisation d'un élevage normal. Ce point, très opportunément rappelé par Menzel (1960), implique notamment que les dispositions seront prises pour que les diverses classes d'âge soient judicieusement représentées dans les élevages et pour lutter contre les maladies et épidémies.

Il est important de considérer que tous les facteurs de la production ont leur rôle à jouer et qu'ils méritent d'autant plus d'attention qu'ils sont loin de leurs conditions optima d'action (Merla, 1962a).

1.2.2 Méthodes biologiques d'accroissement de la production

Ces méthodes sont les suivantes :

(i) Le choix judicieux des espèces;
(ii) Le contrôle et l'adaptation de la mise en charge des étangs;
(iii) Le contrôle de la température des étangs d'élevage;
(iv) Le mélange des espèces et des classes d'âge;
(v) Les productions successives au cours d'une même année;
(vi) Les productions simultanées, animales et végétales, dans l'étang;
(vii) La pratique des pêches intermédiaires;
(viii) L'utilisation de techniques spéciales de pisciculture.

Ces méthodes biologiques d'accroissement de la production en pisciculture vont être traitées ci-après, à l'exception des techniques spéciales (point 8 ci-dessus), qui sont discutées sous forme de points spéciaux du symposium (points 6, 7 et 8). Elles visent notamment la lutte contre les maladies et parasites des poissons, l'utilisation de nouvelles techniques en pisciculture, le contrôle de la reproduction et la pratique de la sélection en pisciculture.

2. CHOIX DES ESPECES

2.1 Conditions requises pour qu'un poisson convienne à l'élevage en pisciculture de production

Tous les poissons ne peuvent convenir à un tel élevage. Pour qu'un poisson se prête à la pisciculture de production de poisson de consommation en étang : 1. il est nécessaire qu'il atteigne une taille suffisante, 2. il est hautement souhaitable qu'il se reproduise dans les étangs d'élevage, et 3. il est très désirable qu'il accepte en abondance une alimentation artificielle à bon marché; 4. il faut aussi que le poisson soit au goût du consommateur et il faut encore 5. qu'il supporte une densité d'élevage suffisamment forte. Il faut également qu'il ne soit pas particulièrement vulnérable aux maladies d'élevage.

2.1.1 Taille du poisson adulte

Un poisson comestible doit atteindre une taille suffisamment grande. Il en résulte que les petites espèces ne peuvent devenir des poissons de consommation, même si elles se reproduisent facilement en étang et si elles acceptent le nourrissage. De ce fait, des espèces comme l'épinoche (*Gasterosteus aculeatus*) en Europe et de nombreuses espèces d'*Haplochromis* en Afrique, qui n'atteignent pas 10 cm de long, ne peuvent convenir en pisciculture, bien que se multipliant très aisément en étang. Il en est de même des petites espèces de *Tilapia*, genre largement utilisé en pisciculture africaine. Le *T. sparmanni* et le *T. margaritacea*, qui n'atteignent pas 20 cm de long, sont à déconseiller.

2.1.2 Reproduction en étangs d'élevage

Afin d'assurer un approvisionnement facile et certain des étangs d'élevage, il est hautement souhaitable qu'un poisson d'élevage se reproduise en captivité. Un poisson ne peut être réellement considéré comme domestiqué que s'il en est ainsi. Si ce n'est pas le cas, l'approvisionnement en poissons de peuplement demeure aléatoire. Certains *Barbus* et *Citharinus* africains ont montré de très belles croissances en étangs, mais leur reproduction ne s'y effectuant pas, leur élevage est demeuré occasionnel.

Il y a cependant des exceptions et le cas le plus connu est probablement celui des carpes dites chinoises (Ctenopharyngodon et autres) dont l'élevage est largement pratiqué en Extrême-Orient, bien que ces poissons ne se reproduisent pas en étangs. Pour ces espèces très appréciées, des efforts importants (voir point 6 du symposium) sont effectués pour obtenir leur reproduction en étangs.

D'autre part, s'il est souhaitable que les poissons d'élevage se reproduisent en étangs d'élevage, leur reproduction trop aisée pose également des problèmes; c'est le cas des tilapias.

2.1.3 Alimentation artificielle

Afin d'obtenir des productions quantitatives élevées, il est très désirable que les poissons d'élevage acceptent en abondance une alimentation artificielle à bon marché. L'utilisation d'espèces remplissant ces conditions est particulièrement intéressante car elle permet d'obtenir des productions élevées, atteignant ou dépassant même 10 tonnes à l'hectare et par an.

2.1.4 Qualité du poisson de consommation

Il est encore indispensable que le poisson d'élevage soit au goût du consommateur. Ainsi, certains siluridae introduits en Europe (ex. : Ameiurus nebulosus) et se multipliant facilement en étang y sont considérés comme une peste, parce que n'ayant pas la faveur du consommateur. D'autre part, des espèces à croissance relativement lente et à faible pouvoir de multiplication sont élevées en étang parce que hautement appréciées par certains consommateurs. Un poisson très connu de ce type, élevé en Indonésie et en d'autres pays d'Extrême-Orient, est le gouramy (Osphronemus goramy).

2.1.5 Densité d'élevage

Elle doit être suffisante. Certaines espèces, par exemple le brochet (Esox lucius) n'acceptent une densité d'élevage assez forte que jusqu'à un certain âge, c'est-à-dire jusqu'à 6 à 8 semaines seulement. Au delà de cet âge, les brochets s'entre-dévorent et l'élevage de ce poisson n'est plus économiquement intéressant.

2.2 Productions quantitatives diverses

Si les conditions ci-dessus précisées sont satisfaites, le choix de l'espèce ou des espèces retenues pour l'élevage dépend du type de production (quantitative, qualitative, économique) retenu.

Lorsque le type de production est fixé, le pisciculteur a intérêt à choisir des espèces à croissance rapide et susceptibles de donner une production quantitative élevée. Il importe de savoir que dans des conditions identiques les productions quantitatives données par des espèces diverses peuvent être très différentes. Aussi, Huet (1964) distingue-t-il dans son coefficient de productivité k un coefficient k3 relatif à l'espèce de poisson et dans lequel il attribue une valeur 1,0 aux salmonidés et 2,0 aux cyprinidés. Cela signifie que dans un étang d'Europe tempérée, à température estivale égale à 20°C et pouvant convenir de ce fait, aussi bien à l'élevage des salmonidés qu'à celui des cyprinidés, on pourra obtenir dans les mêmes conditions de production, sans nourrissage, une production de 100 kg à l'hectare en salmonidés ou de 200 kg à l'hectare en cyprinidés.

Swingle (1961 et information non publiée) donne des indications similaires relatives à la production dans des étangs d'Alabama (U.S.A.) recevant une fertilisation uniforme. La production de poissons microphages-omnivores (T. mossambica) atteint 900-1400 livres/acre, celle des poissons insectivores (catfish, bluegill) 200-500 liv./acre et celle de poissons voraces (black bass à grande bouche) 70-150 liv./acre.

Ces observations confirment d'autres observations (Kelly, 1957) faites à la même pisciculture d'Alabama et selon lesquelles, dans des conditions similaires, le Tilapia mossambica a accusé une croissance nettement supérieure à celle du bluegill (Lepomis macrochirus). Swingle (1960) a également constaté que, en Alabama, la production du Tilapia mossambica dépasse celle de la carpe commune et de Ictalurus nebulosus marmoratus. Au Texas, Brown (1951) a constaté que la production en poisson de taille marchande du chanel catfish (Ictalurus lacustris) dépasse celle des autres espèces expérimentées et qui comprenaient notamment le black bass à grande bouche (Micropterus salmoides) et le bluegill. L'avantage du chanel catfish se manifeste tant à l'égard du poids absolu de la production qu'à l'égard de la proportion de poissons de taille marchande. De son côté, Hickling (1962) remarque que la production quantitative, dans le cas de l'élevage d'un poisson végétarien, sera supérieure à l'élevage d'espèces ayant d'autres régimes alimentaires, du moins en l'absence de nourrissage.

De récentes observations (Huet et Timmermans, non publié) relatives à trois voraces de un été ont permis de constater les très fortes différences de croissance d'espèces de même âge élevées dans un même milieu convenant également bien aux trois espèces. Dans un étang à carpes de seconde année, dans lequel se trouvaient trois voraces, au titre de poissons d'accompagnement, ceux-ci ont atteint fin octobre, soit après leur premier été de croissance, respectivement les poids moyens de 14,3 g, 32,6 g et 158,8 g pour la perche (Percha fluviatilis), le sandre (Luciperca sandra) et le brochet (Esox lucius), soit des poids individuels dans les proportions de 1,0, 2,3 et 11,1.

Le choix de l'espèce est donc très important pour réaliser la production la plus élevée.

2.3 Introduction et substitution d'espèces

Dans l'optique des précisions ci-dessus développées, notamment en ce qui concerne les productions quantitatives diverses de différentes espèces, il peut être intéressant de remplacer une espèce peu ou modérément productive par une espèce quantitativement ou économiquement plus intéressante.

En ce qui concerne la production quantitative, il y a intérêt à choisir des espèces à chaîne alimentaire aussi courte que possible. Par contre, pour ce qui a trait à la production économique, on peut avoir intérêt à produire des voraces, du moins à titre de production secondaire, du fait de la valeur unitaire élevée de ces poissons.

Les conditions données ci-dessus (2.2) d'après Swingle et Hickling montrent que, du point de vue de la production quantitative, il y a intérêt à élever des espèces microphages-omnivores ou végétariennes, ou bien encore se nourrissant de détritus. Un intérêt additionnel de ces espèces non voraces est qu'elles sont tolérantes à l'égard d'autres espèces que l'on peut donc leur associer (Hora et Pillay, 1962).

En conséquence, là où l'élevage de poissons végétariens ou omnivores et acceptant en outre une alimentation artificielle à base d'aliments végétaux et bon marché est possible, il y a intérêt à porter son choix sur de telles espèces, du moins pour former l'un des éléments essentiels du peuplement. De là l'intérêt des tilapias en Afrique et dans les autres régions intertropicales.

C'est l'intérêt offert par les espèces herbivores au point de vue de la production quantitative et aussi pour favoriser le maintien de l'état sanitaire des étangs qui explique les efforts tentés depuis dix ans pour acclimater certaines carpes chinoises, notamment Ctenopharyngodon idella et Hypophthalmichthys molitrix en Europe (Chimits, 1958; Schäperclaus, 1963b; Scheer, 1964).

Toutefois, les introductions d'espèces étrangères doivent être faites avec beaucoup de prudence et sous le contrôle d'experts piscicoles (Hofstede, 1952) car ces introductions présentent des dangers réels, tels que l'introduction de parasites ou maladies nouveaux, ou encore l'invasion des eaux libres où certaines espèces y deviennent une nuisance ou même une peste. Les exemples d'introductions inconsidérées et malheureuses ne manquent pas. D'autre part, les introductions ont été rendues nécessaires car, s'il existe des milliers d'espèces de poissons, très peu d'espèces sont en réalité adaptées à la pisciculture de production en étangs.

2.4 Choix des espèces en Europe

En Europe, le choix des espèces de consommation et de grande valeur commerciale est limité. En fait, le poisson principal et de loin le plus communément cultivé est la carpe (*Cyprinus carpio*). On lui trouve régulièrement associés mais comme poissons d'importance moindre, la tanche (*Tinca tinca*) et, dans certains pays, le gardon (*Gardonus rutilus*). Il est exceptionnel que ces deux espèces jouent le rôle de poisson principal.

A la carpe et éventuellement aux deux autres espèces précitées, on associe souvent, principalement en vue d'augmenter la production économique, des poissons que l'on élève jusqu'au stade de poisson de quelques semaines ou de un été. Il s'agit de deux voraces : le brochet (*Esox lucius*) et le sandre (*Lucioperca sandra*) que l'on élève jusqu'au stade de 6 à 8 semaines pour le premier ou comme estivaux pour le second. Dans le même but d'augmenter la production économique, on élève parfois l'orfe (*Idus melanotus*), poisson d'ornement de grande valeur marchande.

Il a été dit ci-dessus (2.3) que dans certains pays d'Europe, principalement en Europe centrale et orientale, on prête de plus en plus d'attention à certains cyprinidés asiatiques.

Il faut mentionner l'intérêt réel présenté dans certaines eaux chaudes (jusqu'à 29°C comme maximum de température journalière et 26°9 de température mensuelle maximum) par des poissons habituellement considérés comme poissons d'eau froide, à savoir la truite arc-en-ciel (*Salmo gairdneri*) et accessoirement la truite commune (Calderon, 1965).

Au total cependant le nombre d'espèces actuellement utilisées en Europe est relativement faible. Comme le font remarquer Vibert et Lagler (1961), on manque d'espèces végétariennes et planctonophages et les espèces non carnivores, du fait de besoins alimentaires fort semblables, y font plus ou moins double emploi.

2.5 Choix des espèces en Afrique

La pisciculture est relativement récente en Afrique, sauf en Afrique du Sud et à Madagascar. Au début (De Bont et coll., 1948) et maintenant encore (Bard, 1962; Lemasson et Bard, 1964) elle a été principalement axée sur l'élevage des tilapias. La pisciculture de base repose sur l'association d'une espèce herbivore : *T. rendalli* (= *T. melanopleura*) (Thys van den Audenaerde, 1963) ou *T. zillii*, d'une part et, d'autre part, une espèce omnivore-microphage : *T. macrochir*, *T. nilotica*, *T. galilaea*, *T. mossambica*, *T. nigra*, pour ne citer que les principales (Bard, 1962b). Dans les étangs d'eau saumâtre du Nigeria, on a expérimenté (Maclaren, 1949) deux tilapias (*T. melanopleura* et *T. heudeloti*), divers mugilidae et quelques autres espèces.

Tous les tilapias acceptent une alimentation artificielle intensive et on est ainsi arrivé à produire jusqu'à 10 tonnes de poissons à l'hectare. Malheureusement tous les tilapias se reproduisent avec une trop grande facilité et une grande fréquence, ce qui entraîne rapidement une surcharge numérique des élevages et un nanisme plus ou moins marqué des populations.

L'élevage des tilapias par classes d'âge mélangées, donnant une forte production quantitative, mais de médiocre valeur qualitative, est plus généralement répandu que l'élevage par classes d'âge séparées, de moindre production quantitative mais qualitativement supérieur.

On élève maintenant avec succès en République Centrafricaine et au Cameroun un Osteoglossidae : l'*Heterotis niloticus* (Bard, 1962b). L'intérêt de ce poisson microphage, de croissance très supérieure à celle des tilapias a été souligné par plusieurs auteurs (Lemasson, 1957; Oloniyan et Zwilling, 1963).

La carpe, élevée à petite échelle en Afrique du Sud depuis plus de cinquante ans et introduite à Madagascar depuis 1914 est maintenant cultivée en divers pays du continent africain : Uganda (Rhodes, 1960), Rhodésie du Sud (Maar, 1960), et Nigeria (Federal Fisheries Service, Lagos, 1963). Elle possède une bonne croissance et est considérée comme donnant un produit de très bonne valeur. L'élevage d'autres espèces, de la famille des cyprinidés et des citharinidae, n'a pas donné de résultats encourageants jusqu'à présent.

En vue de contrôler la reproduction excessive des tilapias on leur a parfois associé des petits voraces, notamment *Nemichromis fasciatus* (Gruber et Mathieu, 1959) ou encore *Lates niloticus*.

L'élevage de certaines espèces, tel celui du gambusia (*Gambusia affinis*) (cyprinodontidae) pour lutter contre la propagation du paludisme ou de *Haplochromis mellandi* (cichlidae malacophage) pour combattre les mollusques vecteurs de trématodes, ne relève pas de la pisciculture de production.

3. MISE EN CHARGE DES ETANGS

La mise en charge des étangs cherche à déterminer la quantité optimum de poissons à y déverser de manière à en tirer la production quantitative et qualitative maximum tout en ayant recours aux conditions d'exploitation les plus économiques. La mise en charge dépend de l'étendue et de la productivité des étangs.

La mise en charge poursuit une adaptation exacte, à des conditions chimico-physiques et biologiques déterminées, de l'espèce et surtout du nombre et du poids des poissons déversés. C'est l'un des principaux moyens d'améliorer qualitativement et quantitativement la production.

Dans beaucoup d'élevages et notamment en cypriniculture, la mise en charge doit adapter soigneusement la quantité de poissons déversés à la productivité naturelle, même quand on nourrit artificiellement, car l'utilisation rationnelle et économique de la nourriture distribuée dépend de la quantité de nourriture naturelle produite dans l'étang.

La mise en charge vise à déverser dans l'étang d'élevage un nombre de sujets de chaque espèce et de chaque classe d'âge tel que chaque individu atteigne un poids aussi voisin que possible du poids préalablement fixé et s'en écarte le moins possible ni en plus ni en moins. Il est par conséquent très important que la mise en charge soit faite de manière aussi précise que possible.

3.1 Productivité des étangs

La productivité totale des étangs est égale à la somme de la productivité naturelle, de la productivité due à la fumure et de la productivité due à l'alimentation artificielle.

Productivité totale	=	Productivité naturelle	+	Productivité due à la fumure	+	Productivité due à l'alimentation artificielle
		Nourriture naturelle				Nourriture artificielle

3.1.1 Productivité naturelle des étangs

Elle peut être déterminée par les formules de productivité ou évaluée par les tables de productivité.

3.1.1.1 Formules de productivité naturelle des étangs

La productivité naturelle des étangs est directement proportionnelle à sa valeur nutritive ou capacité biogénique. En effet, l'alimentation du poisson est le facteur qui influence le plus la production quantitative. La nourriture présente dépend elle-même de la nature et de l'abondance de la flore aquatique microscopique et macroscopique. Ces facteurs biologiques dépendent à leur tour des caractères physiographiques (physiques, chimiques, géologiques, géographiques et climatologiques), favorables ou défavorables. L'appréciation de la productivité doit donc porter simultanément sur l'étude des caractères physiographiques et sur l'appréciation de la capacité biogénique.

La capacité biogénique est l'expression de la valeur nutritive d'une eau examinée au point de vue de l'alimentation des poissons. Cette notion a été créée par Léger (1910). On la désigne par le signe abréviatif B et elle s'exprime sous une forme chiffrée, appelée "échelle de capacité biogénique", dont les degrés, correspondant chacun à une certaine valeur nutritive, vont de I (capacité biogénique la plus faible) à X (capacité biogénique la plus forte). A ce point de vue, on classe les eaux douces en trois catégories : 1°) les eaux pauvres, à capacité biogénique comprise entre I et III; 2°) les eaux moyennes, à capacité biogénique comprise entre IV et VI; 3°) les eaux riches, à capacité biogénique comprise entre VII et X.

L'appréciation de la capacité biogénique n'est pas susceptible d'une évaluation précise. C'est plutôt une affaire de jugement que de mesure. C'est donc une méthode empirique mais toutes les autres appréciations de la productivité naturelle des étangs le sont tout autant, sinon plus. Utilisée par des personnes expérimentées, elle donne des résultats très acceptables.

Le calcul de la productivité naturelle des étangs dérive des formules énoncées par Léger (1910) pour les eaux courantes. Elle s'évalue par la formule suivante (Huet; 1949) :

$$\boxed{K = \frac{Na}{10} \times B \times k}$$

La productivité annuelle d'un étang (K), exprimée en kilos, est égale au nombres d'ares (1) donnant la superficie de l'étang (Na), multiplié par la capacité biogénique (B = 1 à X), multiplié par un coefficient variable (k) (coefficient de productivité) et divisé par 10.

Le coefficient k, appelé coefficient de productivité (Huet, 1949 et 1964) varie selon les caractères physiques (température moyenne) (k1), chimiques (k2), les espèces de poissons (k3) et leur âge (k4). Ses valeurs pour les eaux cyprinicoles sont normalement comprises entre 2.0 et 4.5 dans les eaux tempérées et entre 8.0 et 18.0 dans les eaux intertropicales. Il en résulte que la production naturelle à l'hectare d'étangs à cyprinidés peut varier entre 20 kg (B = 1 (eau très pauvre) et k = 2) dans un mauvais étang des régions tempérées et 1.800 kg (B = 10 (eau très riche) et k = 18) dans un étang riche des régions équatoriales.

3.1.1.2 Tables de productivité naturelle des étangs

Les tables de productivité, citées par Schäperclaus (1933, 1961), d'après les travaux de Walter pour les étangs à carpes d'Europe centrale, donnent une productivité naturelle appartenant à une des classes ci-après :

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(1) un are = 100 mètres carrés = 10 x 10 m = 1/100 d'hectare = 1/40 d'acre.

Classe de production	I	400 - 200 kg/ha
" "	II	200 - 100 kg/ha
" "	III	100 - 50 kg/ha
" "	IV	50 - 25 kg/ha
" "	V	< 25 kg/ha

Ces tables de productivité sont valables pour des étangs mis en charge avec des carpes de 2 ans. En cas d'empoissonnement avec des carpes de 1 an, ces valeurs sont à majorer de 40% environ (Schäperclaus, 1961).

3.1.2 Productivité totale des étangs

3.1.2.1 Composantes de la productivité totale des étangs

Cette productivité englobe la productivité naturelle, la productivité due à la fumure et la productivité due à l'alimentation artificielle.

3.1.2.1.1 L'appréciation de la productivité naturelle a été exposée ci-dessus.

La productivité naturelle est très importante, du moins dans certains types de pisciculture, par exemple en carpiculture. Merla (1962) et Hepher et Chervinski (1965) insistent sur le fait que l'amélioration de la productivité naturelle est le premier objectif à atteindre pour augmenter la production finale.

3.1.2.1.2. L'augmentation de productivité due à la fumure repose sur une augmentation de la quantité de nourriture naturelle initialement présente. L'étude de la fumure des étangs et de ses conséquences sur la production piscicole fait l'objet du point 2 à l'ordre du jour du symposium. Habituellement, le supplément de production dû à la fumure est compris entre 50 et 100% de la production strictement naturelle. Si l'on accepte que l'augmentation de production due à l'action de la fumure représente une augmentation des 2/3 de la production naturelle initiale, la production naturelle globale est de 3/3K + 2/3K = 5/3K.

En se basant sur les résultats d'expériences relatives à la carpiculture européenne, Schäperclaus (1963a) propose de distinguer la "production naturelle" proprement dite (Naturzuwachs) de la "production naturelle calculée" (rechnerischen Naturzuwachs), laquelle correspond à l'ensemble de la production naturelle proprement dite et de la production naturelle due à l'action de la fumure.

3.1.2.1.3 Dans la plupart des élevages, la productivité correspondant à la productivité naturelle calculée, peut encore être augmentée par la productivité correspondant à l'alimentation artificielle, si celle-ci est utilisée, ce qui est recommandable chaque fois que cela est possible. L'étude de l'alimentation artificielle des poissons fait l'objet du point 3 de l'ordre du jour du symposium.

Il est à noter que l'augmentation de production due à l'utilisation de l'alimentation artificielle entraîne parallèlement une augmentation de la production naturelle calculée. Cette dernière augmentation résulte de l'augmentation importante de la mise en charge et probablement aussi de l'action indirecte de fumure due à l'utilisation de l'alimentation artificielle. Selon Schäperclaus (1963a) l'augmentation de la production naturelle calculée est de l'ordre de 60 pourcent, ce qui a pour effet de presque tripler la production naturelle simple initiale, selon le calcul ci-après : production naturelle globale égale = K (production naturelle initiale + $\frac{2}{3}$ K (fumure) = $\frac{5}{3}$ K + ($\frac{6}{10e}$ de $\frac{5}{3}$ K) (action indirecte de l'alimentation artificielle = $\frac{30}{30e}$ K ou 1 K), soit au total K + $\frac{2\ K}{3}$ + K = 2 K $\frac{2}{3}$. Schäperclaus désigne cette production naturelle globale du nom de production naturelle effective (effektive Naturzuwachs), si bien que l'on a, dans le cas de l'exemple ci-dessus relatif à l'élevage intensif de la carpe en Europe centrale :

K = production strictement naturelle,

$\frac{5}{3} K$ = production naturelle calculée,

$2 \frac{2}{3} K$ = production naturelle effective.

Cette production peut, selon Schäperclaus (1963a) être obtenue dans le cas où l'on cherche à quadrupler la production naturelle calculée par l'emploi de l'alimentation artificielle et à établir la relation suivante : 1/1,5 entre la production naturelle effective et la production due à l'alimentation artificielle.

On vient de voir que, par l'emploi simultané de la fumure et du nourrissage, la production naturelle peut être considérablement augmentée, à condition toutefois d'augmenter proportionnellement la mise en charge.

Les données ci-dessus mentionnées par Schäperclaus montrent dans quelle mesure on peut intensifier l'élevage de la carpe en Europe. En Afrique, dans l'élevage des tilapias, van der Lingen (1957) mentionne que la production naturelle peut être triplée par la fumure et septuplée par l'emploi simultané de la fumure et du nourrissage. Des valeurs plus élevées ont été obtenues.

En pisciculture intensive des tilapias, le nourrissage intensifié de ces poissons accélère leur croissance si bien qu'ils atteignent la taille marchande au moment où ils commencent à se reproduire et où ils ne sont pas encore concurrencés par leurs alevins dans le partage de la nourriture disponible (Charpy, 1956). Il en résulte une amélioration qualitative de la production.

3.1.2.1.4 Selon les cas et le désir d'intensifier plus ou moins fortement la production d'un étang, la productivité totale est donc égale : a) à la productivité naturelle seule, si l'étang n'est pas fumé et si les poissons ne sont pas nourris, b) à la somme de la productivité naturelle plus la productivité due à la fumure, si on fume mais ne nourrit pas, c) à la productivité naturelle plus la productivité due au nourrissage si on nourrit mais ne fume pas, d) à la somme de la productivité naturelle, de la productivité due à la fumure et de la productivité due au nourrissage, si on fume et nourrit.

3.1.2.2 Variations de la productivité totale des étangs.

La productivité totale des étangs peut varier en fonction de diverses circonstances qu'il importe de connaître, afin que la production effective, naturelle et artificielle, soit aussi élevée que possible.

3.1.2.2.1 La production est plus élevée si on mélange les espèces et les âges, car ainsi on utilise mieux les différentes ressources alimentaires d'un étang. Cette question sera développée ultérieurement (point 5).

3.1.2.2.2 Une mise en charge élevée quant au nombre de poissons provoque une meilleure utilisation de la nourriture naturelle qu'une mise en charge réduite, le nombre de chercheurs étant plus élevé dans le premier cas. Il en résulte une production quantitative plus élevée.

Les avantages d'une mise en charge numérique élevée ont été mis en lumière il y a longtemps déjà par les recherches effectuées à Wielenbach (Bavière) par Walter (1931; 1934) et à Eberswalde (Prusse) par Contag (1931). Ils ont été plus récemment exposés à nouveau par Schäperclaus (1960b; 1963), qui a démontré que l'accroissement total le plus fort dans un étang n'est pas atteint quand chaque pièce atteint individuellement le poids le plus élevé. La mise à l'eau de sujets de petite taille conduit à des productions à l'hectare plus élevées que celles obtenues avec de gros sujets.

Une mise en charge numérique élevée entraîne à la fois une augmentation de la production totale et une diminution en poids et taille des poissons produits. Inversement, une mise en charge réduite a pour conséquence une augmentation, parfois très forte, de la croissance individuelle des poissons, toutefois non accompagnée d'une augmentation de la production totale de l'étang (Swingle, 1957 et Marek, 1952).

Les avantages d'une densité élevée de la population sont les suivants (Schäperclaus, 1960b) :

(i) Par suite d'un plus grand nombre de chercheurs, une plus grande partie de la nourriture naturelle est utilisée.
(ii) L'utilisation accélérée de la nourriture présente entraîne un développement corrélatif bien plus rapide de la nourriture restante et de ce fait une augmentation de la production globale de nourriture.
(iii) En carpiculture, l'augmentation du nombre de bouches intensifie le travail du fond de l'étang, ce qui est très important. a) Il en résulte une meilleure et plus rapide utilisation des matières nutritives stockées dans la vase et mises en solution dans l'eau du fait du travail du sol par les carpes. Cela a pour conséquence une production nutritive accrue. b) Il en résulte aussi un trouble de l'eau, ce qui favorise le contrôle de la végétation aquatique supérieure.
(iv) La mise en charge élevée est surtout intéressante si l'on a recours à une alimentation intense des poissons. Il en résulte un important effet indirect de fumure (Müller et Merla, 1962) car une partie des aliments distribués peut être perdue et se décomposer dans l'étang, mais surtout les poissons nourris évacuent, sous forme d'excréments, des quantités importantes de matières nutritives minérales et organiques, qui ont une action fertilisante.

D'après Schäperclaus (1960b) les mises en charges élevées font le mieux apparaître les conséquences favorables de la fumure sur la production quantitative.

3.1.2.2.3 Taille des poissons déversés et cultivés. La productivité augmente en fonction inverse de la taille des poissons déversés et cultivés.

La ration d'entretien des poissons que l'on élève étant d'autant plus forte que la taille des poissons est grande, on aura une utilisation de la nourriture naturelle d'autant meilleure, au point de vue de l'augmentation en poids, que le poids moyen des poissons déversés sera faible et que le poids moyen des poissons marchands récoltés sera faible également.

De ce fait, Schäperclaus (1937) recommande, en vue d'augmenter la rentabilité des étangs, de produire des carpes de consommation de 1.250 g, c'est-à-dire d'un poids nettement inférieur à celui des poissons produits antérieurement, qui était de 1.500 g.

Swingle (1961) a également constaté que le poids que peut supporter une superficie déterminée d'étang (un acre) augmente quand le pourcentage de petits poissons-fourrage augmente et diminue quand le poids total des prédateurs augmente ou bien quand augmente le pourcentage des poissons marchands. Il remarque aussi justement à ce propos qu'une différence dans la capacité de production de deux étangs ne signifie pas nécessairement une différence dans leur productivité, même si la population des deux étangs est formée des mêmes espèces. La différence de production peut très bien résulter de différences dans la proportion des espèces et de leurs classes d'âges.

Bard (1962) constate également que la production de tilapias élevés par la méthode des classes d'âge séparées, où dominent les poissons d'assez forte taille atteint les 2/3 seulement de la production obtenue dans les étangs où les classes d'âges sont mélangées et où dominent les jeunes poissons de petite taille.

Par ailleurs on a déjà signalé (3.1.1.2) que la productivité naturelle des étangs empoissonnés en carpes de 1 an est 40 pourcent supérieure à celle des étangs empoissonnés en carpes de 2 ans.

3.1.2.2.4 Les *étangs nouvellement mis sous eau* ont pendant un à deux ans, une productivité supérieure à celle des vieux étangs (Yashouv, 1959). Il s'agit là d'un effet momentané de mobilisation de matières nutritives jusqu'alors inexploitées.

3.1.2.2.5 En conclusion, on peut formuler les constatations et recommandations suivantes.

La production d'une surface déterminée d'étang s'accroît quand la mise en charge numérique augmente et inversement. Par contre, la croissance individuelle s'accroît quand la mise en charge numérique diminue et inversement (Huet, 1960).

En pratique, il y a intérêt à adopter une densité de population assez élevée et une taille moyenne faible, plutôt qu'une faible densité et un poids moyen élevé. Dans les étangs faiblement productifs, on réduit simultanément le nombre de poissons déversés ainsi que la croissance désirée.

3.1.2.2.6 Il y a cependant *une limite à la mise en charge*, limite variable selon les espèces et, pour chaque espèce, selon l'âge et les dimensions des individus, ainsi que selon les modalités plus ou moins intensives de l'élevage.

Si l'on adopte une mise en charge exagérée quant au nombre, il en résulte une production plus élevée qu'avec une mise en charge normale, mais la croissance individuelle demeure fort au-dessous de la normale. Si l'on dépasse fortement la mise en charge normale, il en résulte le nanisme par manque de croissance, ce qui entraîne d'autre part le gaspillage de la nourriture d'engraissement. Schäperclaus (1933) a pu établir qu'en carpiculture une croissance pratiquement nulle correspondait à une mise en charge 16 fois normale. Dans une étude plus récente (Schäperclaus, 1960a), il constate qu'une mise en charge 6 fois normale (par rapport à la mise en charge correspondant à la production strictement naturelle) en ayant recours à la fois à la fumure et au nourrissage, entraîne encore une exploitation avantageuse. En conséquence, il recommande vivement les mises en charge à forte densité numérique. Toutefois, en ce qui concerne la limite supérieure à ne pas dépasser en carpiculture elle doit être déterminée de manière telle (Schäperclaus, 1961) que l'accroissement de poids individuel ne soit jamais inférieur à 200 pourcent du poids à l'immersion.

On a constaté (Müller et Merla, 1964) qu'une mise en charge nettement élevée a comme première conséquence un affaiblissement des poissons, insuffisamment alimentés, et comme seconde conséquence un déchet nettement plus élevé parmi ces poissons affaiblis. Le déchet dans de tels étangs peut atteindre le double du déchet constaté dans les étangs non surchargés. Par conséquent, on doit recommander une charge aussi forte que possible de l'étang, mais il faut néanmoins éviter sa surcharge.

L'arrêt de croissance correspondant à des mises en charge très élevées peut être attribué à des causes diverses. Parmi les facteurs qui expliquent l'arrêt de croissance correspondant à une densité maximum de la population, il faut citer en premier lieu la réduction de la nourriture disponible, mais aussi la limitation de croissance résultant de la compétition pour l'espace vital minimum (van Someren et Whitehead, 1961). A ce propos on pense aussi que la dimension des étangs peut influencer la taille maximum des poissons.

Dans des eaux qui ne se renouvellent pas, ce qui est le cas à certaines époques de l'année en Israel, on constate un arrêt de croissance des carpes. Yashouv (1958) estime que dans de telles circonstances il ne faut pas exclure l'hypothèse que l'arrêt de croissance soit dû, en même temps qu'à d'autres facteurs, à l'augmentation de concentration, dans les étangs, des produits d'excrétion de la carpe, qui seraient plus ou moins toxiques pour elle.

A cet égard, Swingle (1957) signale qu'une mise en charge élevée, à raison de 3.000 à 6.000 red cats (*Ameiurus nebulosus marmoratus*) à l'acre empêche la reproduction des poissons comme conséquence d'un effet d'inhibition provoqué par les excrétions des poissons.

3.1.2.3 Productivité totale de l'étang, charge maximum (carrying capacity) de l'étang et population maximum (maximum standing crop) de l'étang.

La manière d'envisager la densité maximum de population que peut supporter un étang, la production maximum qu'il peut donner et la façon de calculer la population qui permet d'obtenir cette production diffèrent selon les auteurs. Beaucoup d'auteurs, européens notamment, s'en tiennent à la productivité totale précedemment définie.

D'autres, (Charpy, 1957) utilisent plutôt la notion de capacité maximum ("carrying capacity") de l'étang, qui est atteinte lorsque la densité maximum de l'étang, c'est-à-dire la densité maximum de la population, exprimée en poids, est obtenue. A ce stade, le poids global de la population piscicole de l'étang n'augmente plus. La capacité de l'étang est en liaison directe et étroite avec les espèces de poissons élevées et la nourriture artificielle distribuée.

D'autres encore (Hickling, 1962) préfèrent parler de population maximum de l'étang ("maximum standing crop") définie par van der Lingen (1957) comme le poids maximum de poissons que peut supporter un étang, sans gain ou perte de poids, compte tenu de la nourriture, naturelle et artificielle, disponible. Hickling a analysé les différents facteurs, biologiques et non biologiques, qui font varier la population maximum de l'étang.

Au total cependant ces trois notions sont très proches l'une de l'autre, voir même pratiquement identiques. En effet, la productivité totale est atteinte lorsque la population maximum, exprimée en poids ou en nombre, est arrivée à la taille ou au poids recherché, préalablement fixé et auquel correspond la charge maximum de l'étang.

3.2 Mise en charge des étangs

La mise en charge de l'étang doit être calculée de manière à obtenir la production maximum ou encore la population maximum dans le minimum de temps, après quoi on récolte le poisson, soit en une fois, par vidange de l'étang, soit en pratiquant d'abord des pêches intermédiaires. Le calcul de la mise en charge s'établit de manière différente selon que le poisson ne se reproduit pas ou se reproduit dans l'étang durant la période d'élevage. La mise en charge doit être soigneusement adaptée à la productivité de l'étang et elle doit viser à profiter au mieux de la période où la vitesse de croissance est maximum. Cette croissance est assez lente au début; elle augmente fortement ensuite pour diminuer ultérieurement et finalement s'arrêter.

3.2.1 Formule générale de mise en charge

La formule générale de mise en charge des étangs dans lesquels les poissons ne se reproduisent pas durant la période d'élevage est la suivante (Schäperclaus 1933; Huet, 1960; Hora et Pillay, 1962) :

$$\boxed{\begin{matrix}\text{Mise en charge} \\ \text{(Nombre)}\end{matrix} = \frac{\text{Croissance ou Production totale (en kilos)}}{\text{Croissance individuelle (en kilos)}} + \begin{matrix}\text{Déchet} \\ \text{(Nombre)}\end{matrix}}$$

On détermine, en premier lieu, la croissance ou production totale escomptée (production naturelle + production due à la fumure + production due à l'alimentation artificielle).

La croissance individuelle, obtenue par différence entre le poids moyen à la vidange et le poids moyen à la mise en charge est fixée par le pisciculteur dans les limites normales de croissance de l'espèce élevée et d'après les nécessités de l'exploitation. Il a été dit ci-dessus qu'il était souhaitable de produire des poissons marchands de petite taille.

Les pourcentages moyens de déchet sont généralement bien connus pour les diverses classes d'âge des principaux poissons d'élevage.

En ce qui concerne les principales espèces élevées en carpiculture européenne, on trouve des valeurs moyennes relatives à la croissance individuelle et aux pertes moyennes dans Schäperclaus (1933; 1961).

3.2.2 Exemple de calcul de mise en charge d'un étang

Soit un étang de 3,0 ha de superficie, convenant à l'élevage de la carpe et dont la capacité biogénique est évaluée à VI. Les eaux sont alcalines. On désire y élever des carpes de troisième année, dont la croissance individuelle escomptée est de 1 kilo; le déchet prévu est de 5 pourcent. On attend de la fumure un accroissement de la production naturelle de 66 pourcent et on désire quintupler la production naturelle calculée.

La productivité naturelle de l'étang est la suivante (voir formule 3.1.1.1), le coefficient k étant égal, en l'occurrence, à 3,0 :

$$K = Na/10 \times B \times 3{,}0 = \frac{300}{10} \times 6 \times 3 = 30 \times 6 \times 3 = 540 \text{ kg.}$$

La productivité due à la fumure est évaluée à $540 \times \frac{2}{3} = 360$ kg, ce qui porte la productivité naturelle calculée à 540 + 360 = 900 kg.

La productivité totale, égale au quintuple de la production naturelle calculée, sera de 900 x 5 = 4.500 kg.

La mise en charge devra être : 4.500/1 + 5% = 4.500 + 225 = 4.725 K2.

3.2.3 Mise en charge avec des poissons se reproduisant durant la période d'élevage.

Dans les étangs dans lesquels on élève des poissons qui se reproduisent durant la période d'élevage, la mise en charge se calcule différemment. Il ne faut pas déterminer le nombre de poissons à déverser, mais bien le poids. C'est notamment le cas des élevages de tilapias par classes d'âge mélangées. Les poissons se reproduisent très vite et l'on se trouve rapidement en présence d'une population numériquement trop abondante, dans laquelle prédominent les poissons de petite taille, sans grande valeur commerciale. Dans de telles conditions la production quantitative est aisée mais la production qualitative de poissons marchands plus ou moins bien calibrés est difficile.

Les données précises sur la quantité de poissons, exprimée en poids et à déverser, sont assez peu nombreuses. Généralement, on peut estimer que le déversement d'un poids moyen plus ou moins égal à 10 pourcent du poids de la récolte escomptée peut être recommandé. Certains auteurs (De Bont, 1952) ont préconisé des mises en charge élevées allant jusqu'à 20 pourcent en poids de la récolte espérée. Van der Lingen (1957a) mentionne des mises en charge atteignant 25 pourcent de la production escomptée, dans les étangs non fumés et des mises en charge dépassant 25 pourcent dans les étangs fumés et nourris. Lessent (1959) indique que la mise en charge ne doit pas être inférieure à 5 kg l'are en pisciculture familiale exploitée par la méthode des classes d'âge mélangées.

4 CONTROLE DE LA TEMPERATURE

4.1 Influence de la température sur la production piscicole

Parmi les facteurs externes qui influencent le plus la production piscicole, l'un des plus importants est la température. Chaque espèce de poisson est adaptée à une gamme de températures, qui comporte une température minima et une température maxima, en dehors desquelles la vie du poisson n'est pas possible et aussi une gamme de températures intermédiaires auxquelles correspond la croissance maxima du poisson et également la production maximum de l'étang.

Dans les limites supportées par les poissons d'élevage, les températures élevées sont les meilleures et l'on a constaté que les années à température estivale sont de bonnes années de production. Ce fait a été fréquemment souligné (Merla, 1962a; Timmermans, 1962. Cependant, ainsi que l'a exposé Thienemann (1959), la production plus élevée des eaux des régions chaudes n'est pas due au fait que ces eaux sont plus riches en nourriture que les eaux des régions tempérées. La quantité de plancton présente à un moment donné dans un lac tropical est à peu près la même que dans un lac tempéré. Ce qui différencie les lacs et étangs de ces deux régions c'est le fait que le rythme de production est plus rapide du fait que la température est plus élevée et plus fréquent du fait que, dans les régions tropicales, il se maintient durant toute l'année, alors qu'il ne s'effectue que durant une partie de l'année dans les régions tempérées. A une élévation de température moyenne de 10°C correspondrait un rythme de production 2 à 3 fois plus rapide.

Se basant sur des données de productions réelles obtenues avec les mêmes espèces et notamment avec la carpe dans des régions différant fortement au point de vue de la température annuelle moyenne, Huet (1964) a proposé de donner les valeurs ci-après au coefficient k_1 (facteur température) de son coefficient de productivité : $k_1 = 1.0$ si la température annuelle moyenne est égale à 10°C, $k_1 = 2.0$ si cette température est de 16°C, $k_1 = 3.0$ si elle est de 22°C et $k_1 = 4.0$ si elle égale 28°C. Si cette proposition, qui demande à être vérifiée, est exacte, cela signifie que la production de deux étangs similaires, peuplés des mêmes espèces et quantités de poissons, sera 3 fois plus forte dans un étang à température annuelle moyenne de 22°C (région tropicale) que dans un étang à température annuelle moyenne de 10°C (région tempérée froide).

4.2 Exigences des poissons d'eau chaude à l'égard de la température

La température influence considérablement les différentes activités vitales des poissons. De nombreuses recherches ont été faites en ce domaine (Hela et Laevastu, 1962). La température influence notamment la croissance et la reproduction des poissons (époque de la reproduction et époque préparatoire à celle-ci). Il n'est pas nécessaire d'analyser les multiples données établies en ce domaine. Qu'il suffise d'en rappeler quelques unes relatives à la carpe et aux tilapias.

La carpe peut supporter de très fortes variations de température, bien que les températures plus ou moins propices à son développement soient comprises entre 10 et 33°C (Reichenbach-Klinke, 1965). On peut admettre que les températures les plus favorables à sa croissance sont comprises entre 33 et 20°C. (en Allemagne, d'après Merla (1962a), la meilleure croissance de la carpe est obtenue en juillet et août, alors que la température de l'eau est supérieure à 20°C); la croissance est réduite entre 20 et 13°C, très faible entre 13 et 5°C et nulle sous cette valeur, bien que les jeunes carpes s'alimentent encore à 4°C. La température de reproduction optimum est comprise, en Europe, entre 17 et 23°C.

Les tilapias supportent des températures aussi élevées que la carpe et leur optimum de développement se situe également au-dessus de 20°C. Mais ces poissons ne supportent pas des températures aussi basses que la carpe. Beaucoup d'espèces souffrent et meurent au-dessous de 12°C bien que certaines espèces (*T. sparmanni*) supportent 8°C. Pour leur reproduction, la plupart des tilapias demandent au moins 21 à 23°C.

4.3 Mesures propres à contrôler la température des étangs

Il est évident qu'il y a un intérêt majeur à mettre les poissons d'élevage dans les meilleures conditions correspondant à leurs exigences de reproduction et de croissance. Toutefois, il est beaucoup plus difficile d'influencer la température d'un étang que d'améliorer d'autres moyens influençant la production, comme la fumure ou l'alimentation artificielle par exemple.

Néanmoins, si les possibilités sont limitées elles sont réelles. Depuis longtemps, on utilise en Europe un étang réchauffeur et des abris latéraux pour augmenter la température de l'eau des frayères à carpes. On peut contrôler la température des étangs d'accroissement en réglant la quantité d'eau qui y est admise. En période chaude, si on veut relever la température de l'eau dans l'étang, on réduira le débit d'adduction; si on veut abaisser la température, on augmentera le débit. Il y a souvent intérêt à augmenter la température. Mais il peut aussi y avoir intérêt à la diminuer. C'est le cas si la température est trop élevée et dépasse 33°C, ce qui entraîne une diminution de la croissance des carpes. C'est également le cas dans les élevages de tilapia dont on voudrait abaisser la température au-dessous de 20°C en vue d'annihiler la reproduction. En pareil cas la diminution de production quantitative serait plus ou moins compensée par une amélioration de la production qualitative.

Dans certaines situations, là par exemple où l'on pourrait utiliser l'eau de réfrigération d'une centrale électrique, on pourrait augmenter la production comme conséquence d'une élévation de la température de l'eau des étangs d'élevage, ce qui permettrait l'élevage de poissons des régions tropicales dans les régions tempérées (Chimits, 1958).

4.4 Autres éléments connexes influençant la productivité

A ce propos, on peut noter les deux éléments ci-après :

4.4.1 On constate en Europe que les étés humides, même si la température moyenne n'est pas élevée, entraînent des productions relativement bonnes. Cela résulte probablement du fait que les pluies abondantes amènent dans les étangs, avec les eaux de ruissellement, des matières nutritives enlevées aux terrains arrosés. En outre, le plan d'eau des étangs se maintient à un niveau plus élevé, ce qui a pour conséquence d'éviter l'assèchement des parties peu profondes et par conséquent d'augmenter la surface de production.

4.4.2 Une augmentation de la profondeur des étangs est d'ailleurs souhaitable, du moment qu'elle reste dans les normes admissibles. Hickling (1950) rapporte à cet égard que les pisciculteurs chinois disent qu'un pouce de plus de profondeur de l'étang se traduit par un pouce de plus sur la longueur du poisson. L'augmentation raisonnable de la profondeur augmente l'espace vital nécessaire au poisson. Il faut en tout cas éviter qu'une profondeur insuffisante entraîne, par temps de sécheresse, un assèchement partiel de l'étang par suite de l'abaissement du plan d'eau. L'influence directe d'une profondeur suffisante sur la production est soulignée par Shimadate et coll. (1957).

5 MELANGE DES ESPECES ET DES CLASSES D'AGE

Le mélange des espèces et des classes d'âge est largement utilisé en pisciculture. L'objectif général poursuivi est l'amélioration de la production quantitative, qualitative ou économique. Toutefois, les objectifs particuliers peuvent être très divers et les techniques utilisées pour les atteindre très différentes également. Les principaux cas à envisager sont les suivants :

a) Mélange des classes d'âge d'une même espèce et mélange d'espèces non-voraces, en vue d'augmenter la production quantitative de poisson de consommation;

b) Mélange d'espèces non-voraces et de petits voraces, en vue d'augmenter la production économique, par la recherche simultanée de productions complémentaires;

c) Mélange d'espèces non-voraces et de voraces, en vue d'augmenter la production qualitative des non-voraces en réalisant par les voraces le contrôle de la reproduction excessive des non-voraces.

d) Mélange d'espèces non-voraces, jouant le rôle de "forage fish" pour les poissons voraces, de plus forte taille et dont l'élevage constitue le principal objectif de l'opération. Pour être réalisé, cet élevage fait appel à la théorie des populations équilibrées.

5.1 Mélange des classes d'âge d'une même espèce et mélange d'espèces non-voraces

L'objectif principal d'un tel mélange est d'obtenir une production quantitative de poissons marchands aussi élevée que possible.

Il va de soi qu'une première mesure à utiliser à cette fin et ce, quel que soit le type d'élevage, est d'empêcher l'entrée dans les étangs d'espèces indésirables et qui constituent pour les poissons d'élevage des concurrents de nourriture ou des ennemis plus ou moins dangereux. Parmi ces espèces indésirables, on peut citer en Europe, entre autres, la perche commune, la perche-soleil, le poisson-chat; en Afrique, Haplochomis et autres petits cichlides. Le moyen le plus efficace d'écarter ces espèces indésirables est le placement d'une grille horizontale à ouvertures plus ou moins fines à l'adduction d'eau.

5.1.1 Mélange de diverses classes d'âge de la même espèce.

Ce mélange est l'un des moyens les plus simples d'augmenter la production quantitative d'un étang. Les poissons d'âges divers d'une même espèce ont des régimes alimentaires plus ou moins différents et, si on mélange les âges, on obtient une meilleure utilisation de la nourriture présente dans l'étang et une élévation de sa production.

Cette méthode, connue sous le nom de méthode des classes d'âge mélangées ou de méthode mixte, est largement utilisée en Afrique, dans l'élevage des tilapias (De Bont, 1952; Bard, 1962a). Elle est également couramment utilisée en Israel dans l'élevage de la carpe. Marek (1957) recommande l'élevage simultané en Israel de carpes de consommation et de jeunes poissons (mixed stocking) pesant respectivement, à la récolte, 450 et 80 g environ. Pour éviter la concurrence nutritive il recommande de ne pas dépasser le poids de 100 g pour les jeunes carpes à la récolte. Le mélange des classes d'âge est également utilisé en Europe (Huet et Timmermans, 1966) dans l'élevage de la carpe. Van Someren (1961) constate que, dans des étangs fortement chargés de différentes classes d'âge de Tilapia nigra, ces diverses classes d'âge ne paraissent pas entrer en compétition et ne gênent pas leur croissance mutuelle.

5.1.2 Mélange d'espèces diverses non voraces

Ce mélange est très souvent recommandé et pratiqué. L'opinion générale est que, même en culture intensive, une seule espèce n'est pas capable d'utiliser complètement les ressources alimentaires d'un étang, les préférences alimentaires d'une espèce étant généralement plus ou moins sélectives. C'est le cas notamment de la carpe, qui n'utilise pas suffisamment le plancton ou ne consomme pas la végétation aquatique. Il importe donc, pour augmenter la production et aussi pour varier celle-ci, d'ajouter des espèces complémentaires à l'espèce principale.

En ajoutant à l'espèce principale des espèces différentes dans leur alimentation et leur comportement, la compétition entre ces espèces ne sera jamais très forte, l'utilisation des ressources alimentaires de l'étang sera accrue et la production augmentée. Yashouv (1959) signale que la culture mélangée des carpes et tilapias a permis d'élever de 30 à 50 pourcent la production mixte comparée à la production d'une seule de ces espèces.

Yashouv (1965) recommande de suivre les principes ci-après dans le choix des espèces secondaires : a) les poissons secondaires doivent utiliser des ressources alimentaires non consommées par le poisson principal; b) les poissons secondaires doivent atteindre une taille marchande en même temps que l'espèce principale; c) la croissance de l'espèce principale ne doit pas être contrariée par l'adjonction des espèces d'accompagnement.

Les associations d'espèces sont largement pratiquées dans les diverses régions du monde.

Elles sont notamment très répandues en Extrême-Orient (Horn et Pillay, 1962; Huet, 1956) où les types d'association préconisés diffèrent selon les contrées, mais où il n'est pas rare de trouver jusqu'à 4 et même 6 espèces non-voraces associées.

En Israel, on associe normalement à la carpe d'autres espèces, à savoir le Tilapia aurea (=T. nilotica) et le "grey mullet" (Mugil cephalus) (Sarig, 1963). Cependant les proportions de ce mélange doivent encore être précisées.

Pour les détails concernant les associations d'espèces en Extrême Orient, au Proche-Orient, et en Amérique, voir les autres "review papers".

Dès les débuts de la pisciculture africaine, on a recommandé (De Bont et coll., 1948) l'association d'un tilapia phytophage (T. melanopleura) et d'un tilapia microphage-omnivore (T. macrochir). Cette association s'est maintenue mais, selon les régions, on a recours à d'autres espèces phytophages ou microphages (Bard, 1962b; voir 2.5) bien que ce même auteur se demande si l'utilisation d'une seule espèce à croissance particulièrement rapide ne serait pas préférable.

En Europe, les mélanges d'espèces de consommation sont pratiqués depuis très longtemps. Toutefois, on observe une évolution dans la composition des mélanges préconisés. Antérieurement, le mélange classique en cypriniculture était celui de la carpe et de la tanche (Tinca tinca). On constate une opposition grandissante à l'adjonction de tanches dans les étangs à carpes (Schäperclaus, 1961; Müller, 1961; Yashouv, 1965), due au fait que la tanche, bien qu'ayant une chair de qualité mieux appréciée du consommateur que celle de la carpe, a un régime alimentaire voisin de celui de la carpe et constitue pour celle-ci un concurrent trop peu intéressant étant donné sa croissance nettement plus lente. Une tendance (Schäperclaus, 1963b; Woynarovich, 1965) se manifeste en faveur de la culture des carpes chinoises (Ctenopharyngodon idella et Hypophthalmichthys molitrix). Elle repose sur le fait que ces espèces étant végétariennes tireraient parti d'une ressource alimentaire: les végétaux aquatiques, négligée par la carpe et combattraient en même temps de la manière la moins onéreuse le développement indésirable de ces macrophytes.

Il faut signaler qu'en Europe on élève parfois comme poisson secondaire en cypriniculture l'Orfe (Idus melanotus) qui est un excellent poisson rouge d'ornement du fait qu'il atteint une taille assez grande et qu'il se tient en surface des pièces d'eau dans lesquelles il est introduit à titre décoratif. L'adjonction d'orfes dans un étang à carpes améliore sa production économique.

5.2 Mélange d'espèces non-voraces et de petits voraces de complément

Un tel mélange a pour but la production simultanée d'une espèce principale, élevée au titre de poisson de consommation et d'une espèce secondaire représentée par le stade jeune d'un vorace. Cet élevage est assez couramment utilisé en Europe, où l'on produit, dans les étangs d'engraissement à carpes, de jeunes sandres ou de jeunes brochets sous forme de poissons de un été (Steffens, 1960; Spurny, 1961; Herms, 1962).

Ces jeunes voraces ne peuvent être considérés comme des concurrents sérieux de nourriture pour la carpe. Par ailleurs, ils ont une grande valeur économique et ils jouent un rôle de police important, en détruisant les alevins de carpe ou de tanche qui pourraient naître dans les étangs d'engraissement, ou en consommant les poissons indésirables qui s'introduisent dans ces étangs et qui concurrencent la carpe (Huet, 1960).

L'intérêt économique de l'opération est souligné par Steffens qui constate que, dans un étang où l'on a produit, à l'hectare, simultanément 520 kg de carpes et 50 kg de sandres d'un été, la valeur commerciale de la production de jeunes sandres est légèrement supérieure à celle des carpes, dont le poids est 10 fois plus élevé.

5.3 Mélange d'espèces non voraces et voraces de contrôle

C'est principalement en Afrique que l'on cherche à réaliser une telle association, visant à contrôler la reproduction excessive des tilapias et, de ce fait, à augmenter la production qualitative.

Il est bien connu que les tilapias se reproduisent très aisément, trop facilement même et, parmi les diverses méthodes (Huet, 1957) susceptibles de contrôler cette reproduction excessive (selon Bard,(1962a) la production peut compter jusqu'à 75 pourcent de poissons de petite taille), figure l'adjonction aux tilapias d'un vorace de contrôle.

Des succès ont été enregistrés. Toutefois, l'application de la méthode n'est pas encore très fortement généralisée, du fait notamment que, comme toute pisciculture de mélange, elle est assez compliquée d'application pour un pisciculteur indigène.

Gruber et Mathieu (1959) ont décrit une méthode de contrôle de la reproduction des tilapias par un petit cichlide : Hemichromis fasciatus. Ce prédateur d'accompagnement, qui n'offre en soi pas d'intérêt, est capable de contrôler la multiplication des tilapias. Le but poursuivi n'est pas de détruire l'entièreté du frai des tilapias mais bien d'obtenir une multiplication contrôlée, non excessive mais néanmoins suffisante pour la pérennité de l'exploitation. La proportion d'Hemichromis à adjoindre aux tilapias varie selon la méthode d'élevage utilisée.

En Côte d'Ivoire, Lessent (1959) constate que dans un élevage mélangé de tilapias et d'Hemichromis, ce dernier a détruit les alevins de tilapia mais la production totale ne représentait plus que 30 pourcent de celle des élevages sans prédateur.

Selon Pruginin (1965), le contrôle de la reproduction des tilapias est également possible avec Lates niloticus, mais la difficulté dans l'emploi de cette espèce réside dans le fait qu'elle ne se reproduit pas en étang et qu'il faut donc se procurer des alevins dans les eaux libres, ce qui est une sérieuse complication.

5.4 Mélange d'espèces voraces et d'espèces non voraces (forage fish)

Dans un tel mélange, l'objectif principal est la production d'un poisson vorace de belle taille, cultivé comme poisson de consommation ou comme poisson de sport. Pour nourrir le vorace, on lui adjoint une ou plusieurs espèces de poissons non voraces (forage fish), dont la valeur comme poisson de consommation est beaucoup moindre ou même nulle.

Le mélange classique de ce type est celui largement répandu aux Etats-Unis et dont les composantes principales sont le "black bass" à grande bouche (Micropterus salmoides), comme vorace et le "bluegill" (Lepomis macrochirus) ou divers centracrhidés voisins et autres poissons divers comme "forage fish". Des associations similaires sont beaucoup moins souvent réalisées dans les autres régions du monde.

Le maintien d'un tel mélange demande que soit établi un équilibre entre voraces et non-voraces. La théorie de cet équilibre a été développée par Swingle (1940; 1950b). L'une des valeurs principales à déterminer est la valeur A_T (total availability value : valeur totale utilisable) qui donne le pourcentage de la population globale représenté par des poissons de taille marchande suffisante. Dans une population équilibrée, la valeur A_T est comprise entre 33 et 90; une valeur supérieure à 85 indique que l'étang est trop peuplé en prédateurs.

Il est possible que la théorie des populations équilibrées puisse être utilisée ultérieurement en Afrique (Bard, 1962a) avec des espèces locales.

6 PRODUCTIONS SUCCESSIVES AU COURS D'UNE ANNEE

Afin de porter la production piscicole au maximum, il importe de laisser l'étang sous eau et en état de production aussi longtemps que possible. Il y a par ailleurs intérêt à utiliser au mieux la période d'assec séparant deux mises sous eau.

La croissance n'est possible dans les étangs que si la température est suffisante (4.2). Aussi la production est-elle ralentie ou même arrêtée durant une période plus ou moins longue, selon les climats. D'autre part, un assec périodique plus ou moins prolongé est indispensable au point de vue cultural, en vue notamment de favoriser la minéralisation de la vase et d'améliorer l'état sanitaire de l'étang.

En vue d'augmenter la production on peut, dans certains cas, réaliser plusieurs productions piscicoles au cours d'une même année ou bien, dans d'autres cas, pratiquer l'alternance des productions animales ou végétales.

6.1 Productions piscicoles successives au cours d'une année

La manière de réaliser plusieurs productions piscicoles au cours d'une même année diffère fortement selon les climats et l'on doit, à ce point de vue, distinguer entre régions tropicales, régions tempérées chaudes et régions tempérées froides.

6.1.1 Les productions successives dans les régions tropicales

Dans ces régions, la croissance est possible durant toute l'année. Elle est pratiquement continue dans les régions équatoriales. Elle connaît un ralentissement dans les régions tropicales marquées par une ou plusieurs saisons sèches plus froides. Néanmoins, durant celles-ci la croissance se maintient; seule la reproduction est contrariée, ce qui n'est pas toujours un mal. En région tropicale on peut donc, sans difficulté, obtenir plusieurs productions au cours d'une année, avec les mêmes espèces et les mêmes classes d'âge de poissons, si on limite la durée de croissance à six mois environ ou même moins ce qui, en pisciculture des tilapias est souvent recommandable (Charpy, 1958; Lessent, 1959).

6.1.2 Les productions successives dans les régions tempérées chaudes

Ces régions sont caractérisées par un ralentissement sensible de la production durant la saison froide. La saison de croissance s'étend sur six à neuf mois. Durant celle-ci, on peut obtenir plusieurs productions successives dans le même étang, avec les mêmes espèces et les mêmes classes d'âge, comme dans les régions tropicales, à condition de limiter la durée de mise sous eau des étangs. En Israel, Palewski (1957) et Marek (1957) limitent la période de croissance à 105 jours, ce qui permet trois productions successives dans le même étang au cours d'une seule année.

6.1.3 Les productions successives dans les régions tempérées froides

Le problème est très différent dans ces régions car, par suite du climat, les espèces cultivées ne se reproduisent qu'une fois l'an et à une seule époque, alors que les mêmes espèces, également cultivées dans les régions tempérées chaudes et les régions tropicales s'y reproduisent parfois plusieurs fois et en tout cas à plusieurs époques de l'année, ce qui facilite considérablement le problème de la mise en charge des étangs avec des poissons d'âge déterminé. Comme autre conséquence du climat plus froid, la croissance des espèces d'eau chaude est limitée à une période de quatre à six mois.

Dans de telles conditions climatiques, certaines espèces, la carpe notamment, se reproduisent tard : en mai-juin, si bien que dans les étangs réservés à la production de carpillons de première année, la production de ces pièces d'eau ne commence qu'en juin et même en juillet, si on n'y élève que des carpillons d'un été, en partant de carpillons de six semaines produits dans d'autres étangs, dit de premier alevinage. Ces étangs, ainsi exploités, connaissent donc une période de chômage prolongée et une perte de production sensible.

Afin d'éviter ou de réduire le chômage de ces pièces d'eau, on peut y réaliser plusieurs productions successives en y élevant, avant la production du poisson d'eau chaude, un poisson se reproduisant à une période plutôt hâtive. On peut notamment produire dans les étangs à carpillons, avant l'élevage de ceux-ci, une récolte de brochetons de 6 à 8 semaines (Huet et Timmermans, 1958), ce qui augmente de manière très appréciable la production économique de l'étang pour toute l'année.

On peut aussi, et cela est souvent recommandé (Mengel, 1963) consacrer le même étang à la production successive de carpillons de 4 à 6 semaines puis à celle de carpillons d'un été.

Il en résulte que dans les étangs à carpes de première année on peut, dans les régions tempérées froides, y obtenir successivement 2 ou 3 productions, selon les combinaisons suivantes : (i) production de carpillons de six semaines puis de carpillons de un été, (ii) production de brochetons de six semaines puis de carpillons de un été, (iii) production de brochetons de six semaines (fin avril à début juin) suivie de la production de carpillons de un été (mi-juillet jusqu'au printemps suivant). Les résultats obtenus en Belgique par l'application de ces diverses combinaisons ont été récemment analysés par Huet et Timmermans (1966).

6.2 Alternance des productions animales et végétales

Les avantages et même la nécessité de l'assec périodique des étangs sont bien connus. Si la mise à sec ne peut s'opérer chaque année, mais seulement à intervalles plus longs, on prolonge parfois l'assec pendant un an. On peut pratiquer l'assec simple, laissant le sol à nu, ou le combiner avec une culture agricole: c'est l'"évolage". L'évolage est moins courant qu'auparavant; depuis la généralisation de l'emploi des engrais, il a perdu en bonne partie sa raison d'être.

Toutefois, l'évolage n'est pas abandonné partout. Ribianszky (1961) le recommande vivement pour la Hongrie, à raison d'une année sur quatre. L'un des avantages de l'alternance des productions piscicoles et agricoles ainsi pratiqué est de favoriser la lutte contre les maladies des poissons. Menzel (1963) recommande également de laisser de temps à autre à sec les étangs entre deux cultures successives.

Dans les régions tropicales où se pratique la rizipisciculture, l'alternance des productions agricoles et piscicoles est également d'usage courant. Selon certaines méthodes de rizipisciculture (Huet, 1956) on produit alternativement et successivement une culture de riz suivie d'un ou plusieurs élevages de carpillons ou bien d'un élevage de petites carpes de consommation. La durée de l'élevage piscicole n'excède pas six mois.

7 PRODUCTIONS SIMULTANEES, ANIMALES ET (OU) VEGETALES, DANS L'ETANG

Les productions quantitative et économique d'un étang peuvent être augmentées dans des proportions diverses et parfois très importantes par l'élevage ou la culture simultanés du poisson dans l'étang d'une part et, d'autre part, d'autres animaux ou de végétaux dans l'étang, sur celui-ci ou à son voisinage immédiat. Quelques unes de ces productions simultanées sont citées ci-après : poissons et canard, rizipisciculture, mollusques et crustacés, ragondins.

7.1 Poissons et canards

Les avantages de l'élevage simultané des poissons dans l'étang et des canards en surface et à proximité immédiate de celui-ci ont été développés depuis longtemps (Probst, 1934). Ils ont été rappelés récemment par Blume (1960).

(i) Du fait de la répartition régulière des excréments des canards à la surface de l'étang, il en résulte une excellente fumure organique de l'eau et du fond de l'étang, ce qui a pour conséquence une abondante production de plancton, profitable à la carpe. L'élevage des canards peut donc remplacer la fumure ou tout au moins y suppléer.

(ii) En fouillant la vase dans les parties peu profondes, les canards contribuent efficacement à la réduction de la végétation aquatique; le développement de la lentille d'eau en est notamment contrarié.

(iii) Aux endroits fouillés par les canards, la vase est remuée et les matières nutritives qu'elle renferme sont mises en solution ce qui augmente la productivité naturelle.

(iv) La nourriture distribuée aux canards et non utilisée par ceux-ci et qui tombe à l'eau est directement consommée par les carpes ou se décompose dans l'étang et leur profite ensuite par l'action d'une fumure indirecte.

(v) Dans les régions tropicales, Van der Lingen (1959) signale que les canards éliminent les mollusques jusqu'à une profondeur de 1 pied 1/2 et contribuent ainsi à la lutte contre la bilharziose.

(vi) Aux avantages ci-dessus énumérés, il faut ajouter l'intérêt économique résultant de l'engraissement des canards (Schäperclaus, 1961).

De ces divers avantages il résulte une production piscicole accrue. Les pourcentages d'augmentation de la production naturelle cités varient selon les auteurs. Une valeur moyenne est celle donnée par Eppel (1961), selon lequel l'élevage et le nourrissage intensif de 300 canards à l'hectare augmentent en moyenne la production en poisson de 100 kilos. Les densités d'élevage de canards recommandées par les auteurs européens varient entre 200 et 400 canards à l'hectare (en général 250).

L'élevage des canards sur les étangs est largement pratiqué en Europe orientale, spécialement en Allemagne de l'Est, en Pologne, en Union soviétique. Des essais considérés comme très encourageants ont également été tentés en Afrique, spécialement en Rhodésie du Nord (Mortimer et coll., 1963) et en Rhodésie du Sud (van der Lingen). En Rhodésie du Nord on a combiné avec succès dans une petite exploitation rurale indigène, les cultures agricoles, l'élevage de canards et la production de tilapias. Cette combinaison est une bonne manière d'intégrer la pisciculture dans l'exploitation agricole, ce qui est largement pratiqué en Extrême-Orient, où tout fermier est plus ou moins pisciculteur et vice-versa.

7.2 Rizipisciculture

Dans les rizières, on peut associer la culture du riz et l'élevage des poissons. Il a été question précédemment de l'alternance de ces cultures mais on peut aussi cultiver en même temps riz et poisson. En ce cas, la culture principale est celle du riz et la production de poisson est complémentaire. Il en résulte néanmoins des avantages appréciables.

Parmi les avantages de l'association riz-poisson on peut rappeler les suivants :(i) avec un effort minime, on obtient une production supplémentaire de poisson; (ii)le poisson utilise les larves d'insectes, le planoton et les algues qui se développent dans les rizières et qui ne rentrent pas dans le cycle du riz. Les poissons qui mangent des algues restituent rapidement au milieu, par leurs excréments, une partie des éléments aborbés par les algues.

C'est principalement en Extrême-Orient que la rizipisciculture est en honneur (Huet, 1956). En Europe, elle n'a offert antérieurement une certaine importance qu'en Italie, mais cette importance a fortement décru depuis une trentaine d'années (Tonolli, 1955; Hickling, 1962). Sur le continent africain, des essais sporadiques de rizipisciculture ont été tentés en divers endroits. Les essais les plus importants ont été effectués à Madagascar (Kiener, 1963), où l'on escompte un développement de ce type de production. Les poissons utilisés sont la carpe et le *Tilapia mossambica*.

7.3 Mollusques et crustacés

Ils peuvent donner un supplément de production économique très important. Ainsi, dans les étangs d'eau saumâtre (tambaks) d'Indonésie (Huet, 1956), on récolte jusqu'à 200 kg/ha de crevettes et de crabes amenés par l'eau de mer et pénétrant d'eux mêmes dans les étangs. Aux Etats-Unis, Swingle (1949) signale que l'on peut produire jusqu'à 1 000 livres à l'acre de moules sans diminuer la production de poisson. En ce domaine, on ne dispose pas de données positives pour l'Europe et l'Afrique.

7.4 Elevage du ragondin

L'élevage du ragondin (Myocastor coypus) est pratiqué en Europe centrale et orientale et en Israël. Le ragondin n'offre pas les inconvénients du rat musqué, qui affouille les digues. Les avantages de l'élevage du ragondin peuvent se résumer comme suit (Ehrlich-Chimits, 1959): (i) réduction de la végétation aquatique, notamment de Phragmites et de Typha; (ii) accélération de la minéralisation de la vase et de ce fait augmentation de la productivité de l'étang; (iii) augmentation de la nourriture de la carpe, qui se nourrit des excréments du ragondin; (iv) production économique appréciable représentée par la chair du ragondin et par sa peau, qui a une bonne valeur comme fourrure. L'élevage du ragondin entraîne donc une augmentation de la production quantitative et économique de l'étang.

7.5 Productions accessoires diverses

Parmi ces productions, qui accroissent la production économique de l'étang, il faut citer la production de roseaux (Phragmites notamment) qui se développent dans les endroits peu profonds des étangs.

8 PRATIQUE DES PECHES INTERMEDIAIRES

La pratique des pêches intermédiaires est susceptible, dans certains cas, d'augmenter très sensiblement la production d'un étang.

8.1 Opportunité et avantages

On a recours à cette technique lorsque la densité de la population devient trop grande et se rapproche de la charge maxima de l'étang. A ce stade de la production, qui se marque par un ralentissement très net de celle-ci, il faut éclaircir les rangs de la population. Les individus restants ont, à ce moment, plus de place et disposent de plus de nourriture. Leur croissance reprend jusqu'au moment où la charge maximum de l'étang est à nouveau atteinte. A ce moment, on peut procéder à une nouvelle pêche intermédiaire ou bien vider l'étang. En faisant se succéder plusieurs pêches intermédiaires (van der Lingen, 1959a), on peut conserver assez longtemps l'étang à un niveau proche de sa capacité maximum, tout en maintenant à un degré élevé le rythme de la production qui, sinon, serait stoppée dès que la charge maximum aurait été atteinte.

Les pêches intermédiaires peuvent se pratiquer à l'aide d'engins de pêche les plus divers : lignes, nasses, filets tels que seine et épervier ou bien encore en ayant recours au lattis de bambou, ce qui est d'usage courant en Indonésie (Huet, 1956) et est possible si les étangs ne sont pas très profonds.

Ces pêches ne peuvent se répéter indéfiniment. S'il en était ainsi, on passerait à l'exploitation d'une eau libre et on ne ferait plus de pisciculture. Des vidanges périodiques s'imposent pour contrôler la population, empêcher le surpeuplement de l'étang, enlever les espèces indésirables qui se seraient introduites et refaire une mise en charge rationnelle de la pièce d'eau.

8.2 Conditions d'utilisation et modalités d'exécution

Le recours aux pêches intermédiaires se justifie lorsque la population est trop dense. Un tel état peut résulter de deux situations totalement différentes au départ, ce qui entraîne d'ailleurs des modalités d'exécution très différentes également.

8.2.1 Dans un premier cas, la population devient trop dense parce que la mise en charge numérique a, volontairement, été choisie trop forte. La population sera alors composée de plusieurs espèces, souvent à croissances inégales (c'est le cas en Extrême-Orient) ou bien elle sera composée de deux classes d'âge d'une même espèce, la carpe par exemple. Les poissons ne se reproduisent pas dans l'étang. Les pêches intermédiaires ont pour but d'enlever les poissons parvenus à la taille marchande et de laisser en place les espèces ou classes d'âge qui n'ont pas encore atteint la taille commerciale.

8.2.2 Dans un second cas, la densité trop forte de la population résulte d'une multiplication exagérée et non contrôlable des poissons élevés dans l'étang. C'est ce qui se produit dans l'élevage des tilapias par classes d'âges mélangées. Il faut éclaircir les rangs d'une population devenue beaucoup trop dense. C'est ce que l'on a fait en Afrique et à Madagascar en enlevant les plus gros sujets. Cette pratique n'est cependant pas parfaite ainsi que le constatent Charpy (1965), van Someren et Whitehead (1961) et Hickling (1962), car en se limitant à n'éclaircir les rangs que des gros poissons, on diminue la possibilité d'en recruter d'autres, non seulement parce qu'on les a partiellement enlevés, mais aussi parce que les petits poissons survivant et, déjà trop nombreux, vont se reproduire ce qui accentuera encore la densité de la population et la conduira finalement au nanisme. Les pêches intermédiaires devraient donc également éclaircir les rangs des poissons de petite taille.

8.3 Effets sur la production

Outre les avantages précités des pêches intermédiaires, résultant du fait que la production se maintient alors que la population est voisine de la capacité maximum de l'étang, il faut signaler que les mises en charge élevées, auxquelles correspondent une densité très forte de la population dès le début de l'empoissonnement, ont pour conséquence une utilisation complète de la nourriture dès le début de la mise en charge. La production atteint très rapidement un rythme proche de son maximum. En outre aussi les pêches intermédiaires peuvent permettre d'espacer les vidanges et de réduire les pertes de nourriture et de production qui en résultent.

Des données précises manquent sur l'évaluation chiffrée de l'augmentation de production résultant de la pratique des pêches intermédiaires. Yashouv (1959) signale que, en Israël, elles ont permis d'obtenir en un an une production presque double de la charge maximum de l'étang.

8.4 Utilisation

Les pêches intermédiaires ne sont pratiquement pas utilisées en Europe dans les étangs de production. Elles sont d'usage courant en Israël, en Afrique et à Madagascar (Therezien, 1963) ainsi qu'en Extrême-Orient (Chen, 1952).

9 TECHNIQUES SPECIALES DE PISCICULTURE

Il existe encore d'autres moyens biologiques d'augmenter la production piscicole que ceux développés précédemment. Ils sont mentionnés ci-après. Toutefois, attendu que ces moyens font l'objet de points traités spécialement lors du symposium, ils sont simplement cités avec quelques brefs commentaires.

9.1 Lutte contre les ennemis et maladies des poissons

Une production normale et plus particulièrement intensive ne peut être obtenue que si les poissons n'ont pas à souffrir anormalement des attaques de leurs ennemis et maladies. Or on déplore actuellement en Europe, en carpiculture, des déchets considérables, atteignant 40 pourcent et dépassant même 50 pourcent (Menzel, 1960;Muller et Merla, 1964) parmi les carpes,spécialement de seconde année, par suite d'épidémies très intenses de pleurésie infectieuse.

De telles attaques anéantissent les efforts tentés par ailleurs pour améliorer la production par des moyens biologiques et non biologiques. En luttant rationnellement contre les maladies, on peut réduire les pertes dues à celles-ci. Ainsi, Merla et Zelder (1961) ont obtenu par injection d'antibiotiques aux carpes, une amélioration très nette des pertes (9 pourcent au lieu de 20 pourcent) et de la croissance individuelle (augmentation de 16 pourcent pour les carpe traitées). L'obtention de poissons sains et vigoureux est la première condition à réaliser préalablement avant de chercher à intensifier la production.

Les maladies et parasites des poissons d'étang sont traités au point 8 du symposium.

9.2 Sélection et élevage des prédominants

Il est certain que la sélection réserve des possibilités réelles d'accroissement de la production.

Il est bien connu que les différences de croissance considérables existent à l'intérieur d'une descendance de poissons provenant de mêmes géniteurs. Cependant, les méthodes qui permettent de choisir, lors de la mise en charge, les sujets qui plus tard auront la meilleure croissance, ne sont pas encore bien établies.

Bien que de nombreux travaux aient été faits sur le sujet, on ne sait pas encore avec suffisamment de certitude si les différences de croissance qui se manifestent dans le jeune âge se maintiennent ultérieurement. A cet égard, Zarnecki (1964) a pu établir que parmi les carpillons de 4 semaines, ceux qui à cet âge montraient la meilleure croissance conservaient l'avance sur les moins bien venants encore à la fin de leur second été.

Les problèmes de sélection sont traités au point 6 du symposium.

9.3 Monosexculture et culture d'hybrides

Ces pratiques sont susceptibles d'améliorer la production, spécialement la production qualitative d'espèce qui se reproduisent prématurément et abondamment dans les étangs de grossissement, alors que cette reproduction est totalement indésirable. C'est parfois le cas de la carpe et c'est généralement le cas des tilapias. La production est alors fortement dépréciée car en majeure partie formée de poissons de petite taille sans grande valeur commerciale.

Ces méthodes particulières sont étudiées au point 7 du symposium : nouveaux systèmes pour la pisciculture et ne sont citées ci-après qu'à titre d'exemple.

9.3.1 La monosexculture

Elle a donné des résultats positifs en Afrique avec certaines espèces de tilapias, notamment avec Tilapia nigra au Kenya. Brown et van Someren (1953) ont constaté que, dans cette espèce, les mâles ont une croissance supérieure à celle des femelles. A l'âge de 4 à 6 mois, lorsque les jeunes poissons ont environ 10 cm de long, il est possible de séparer les sexes et de ne mettre que des mâles dans les étangs de grossissement. Charpy (1955) a également préconisé l'élevage des mâles de T. melanopleura et T. macrochir.

En Israël, Kessler et coll. (1961) ont fait des essais avec la carpe. La croissance des femelles paraît supérieure à celle des mâles.

9.3.2 La culture d'hybrides

La culture d'hybrides, plus ou moins stériles, permet d'éviter plus ou moins complètement la reproduction indésirable des poissons dans les étangs de grossissement.

Des résultats fort intéressants ont été obtenus en Malaisie (Hickling, 1960) par le croisement de tilapias mâles et d'une souche de T. mossambica originaire de Zanzibar et de femelles de T. mossambica appartenant à la souche répandue en Malaisie et introduite d'Indonésie. La descendance est pratiquement composée exclusivement de mâles.

10 RESUME ET SUGGESTIONS

Notions introductives

La pisciculture de production de poissons de consommation en étang à température élevée peut être examinée à divers points de vue, à savoir ceux de la production quantitative, de la production qualitative, de la production économique.

Quel que soit le type de production, celle-ci peut être augmentée par des méthodes non biologiques: entretien et amélioration des étangs, chaulage et fumure des étangs, nourrissage des poissons, mesures techniques et sanitaires, et par des méthodes biologiques, dont il est question dans la présente étude.

Choix des espèces

Il peut influencer considérablement la production.

Pour qu'un poisson convienne à l'élevage: il est nécessaire qu'il atteigne une taille suffisante, il est souhaitable qu'il se reproduise dans les étangs d'élevage et il est très désirable qu'il accepte en abondance une alimentation artificielle à bon marché. En ce qui concerne ces deux dernières conditions, de nombreuses recherches et progrès demeurent à faire. Le poisson d'élevage doit aussi être au goût du consommateur et supporter une densité de population suffisamment forte.

Dans des conditions écologiques déterminées, la production quantitative, qualitative ou économique peut très fortement varier selon les espèces utilisées. Il y a lieu de rechercher, dans chaque situation, l'espèce ou les espèces qui donnent les productions les plus élevées.

Si l'on vise la production quantitative, il y a lieu de rechercher des espèces à chaîne alimentaire courte, à régime végétarien ou microphage-omnivore et acceptant en abondance une alimentation artificielle à bon marché. Des recherches sont en cours en Europe pour y introduire des espèces végétariennes asiatiques. Il est à remarquer que l'introduction des espèces exotiques doit être faite avec prudence.

En Europe, le principal poisson d'élevage en étang à température élevée est la carpe. Diverses espèces lui sont associées, souvent en vue d'augmenter la production économique. On manque d'espèces végétariennes et planotonophages et les recherches sont à développer en ce secteur.

En Afrique, où la pisciculture est relativement jeune, elle repose sur l'élevage de tilapias. On associe souvent une espèce herbivore à une espèce microphage-omnivore. Les tilapias acceptent une alimentation artificielle abondante mais se reproduisent trop aisément ce qui pose des problèmes non encore résolus. Dans certains pays on élève avec succès la carpe et l'Heterotis niloticus.

Mise en charge des étangs

Elle cherche à déterminer la quantité optimum de poissons à y déverser. Elle dépend de leur étendue et de leur productivité (productivité naturelle, productivité totale).

La productivité naturelle des étangs est proportionnelle à leur valeur nutritive ou capacité biogénique. Celle-ci et par conséquent la productivité naturelle ne peuvent être déterminées que par des méthodes et formules empiriques (formule Léger-Huet et tables de Walter). Il est souhaitable que des méthodes plus précises soient élaborées.

La productivité totale des étangs englobe la productivité naturelle, la productivité due à la fumure et la productivité due à l'alimentation artificielle. Une bonne productivité naturelle conditionne généralement l'obtention d'une productivité globale élevée. La productivité due à la fumure (point 2 du symposium) peut entraîner une augmentation de la productivité naturelle jusqu'à doubler celle-ci. La productivité due à l'alimentation artificielle (point 3 du symposium) peut élever la productivité totale à des valeurs très élevées. Des exemples sont donnés dans le texte.

La productivité totale varie en fonction de circonstances diverses: a) Le mélange des espèces et des classes d'âge augmente la productivité. b) Une mise en charge élevée augmente la productivité tout en entraînant une diminution de la croissance individuelle. c) La productivité augmente en fonction inverse de la taille des poissons déversés et cultivés. Il y a donc intérêt à déverser un nombre élevé de poissons de petite taille plutôt qu'un nombre peu élevé de poissons d'assez forte taille. Il y a aussi intérêt à produire du poisson d'assez petite dimension.

Il y a cependant une limite à la mise en charge, limite variable selon les espèces et les modalités d'élevage. Des recherches sont souhaitées pour préciser ces limites.

Les notions de productivité totale, charge maximum (carrying capacity) et population maximum (maximum standing crop) sont comparées.

La mise en charge des étangs dans lesquels les poissons ne se reproduisent pas durant la période d'élevage s'exprime par une formule numérique qui est exposée et illustrée par un exemple.

La mise en charge des étangs dans lesquels les poissons se reproduisent durant la période d'élevage s'exprime par un poids de poissons à déverser. Des recherches sont indispensables pour établir la manière de le déterminer.

Contrôle de la température

La température influence considérablement et favorablement la croissance des poissons. Le fait est attesté par la production plus élevée dans les eaux tropicales que dans les eaux tempérées. Les valeurs attribuées par Huet à son coefficient de productivité k_1 (température) demandent à être vérifiées.

Les exigences des poissons relativement à la température varient d'espèce à espèce. Les connaissances en ce domaine demandent à être précisées.

Il n'est pas toujours aisé de modifier la température des étangs. Néanmoins des possibilités réelles de réchauffement ou de refroidissement existent.

En dehors de la température, la productivité des étangs est encore influencée par leur profondeur, qui doit être suffisante mais sans excès.

Mélange des espèces et des classes d'âge

Ces mélanges sont fréquemment utilisés en vue d'améliorer la production quantitative, qualitative ou économique. Toutefois, des recherches doivent être poursuivies dans toutes les régions du monde pour définir les meilleures associations d'espèces.

Mélange des classes d'âge d'une même espèce et mélange d'espèces non voraces. De tels mélanges sont réalisés en vue d'augmenter la production quantitative de poisson de consommation par l'utilisation plus poussée des ressources alimentaires d'un étang que par un seul âge d'une seule espèce. Le mélange des classes d'âge de la même espèce est fréquent en pisciculture de la carpe et des tilapias. Les associations d'espèces non voraces sont largement utilisées dans les diverses régions du monde. En Europe, on associe diverses espèces à la carpe, qui demeure l'espèce principale. En Afrique, dès les débuts de la pisciculture on a associé un tilapia phytophage et un tilapia microphage-omnivore.

Mélange d'espèces non voraces et de petits voraces de compléments.- Un tel mélange, assez souvent utilisé en Europe, vise à produire du poisson de consommation: la carpe et, à titre secondaire, un jeune vorace: brochet ou sandre d'un été. Un mélange peut augmenter fortement la production économique.

Mélange d'espèces non voraces et de voraces, en vue d'augmenter la production qualitative des premières.- Ce mélange est parfois réalisé en Afrique, en élevage des tilapias auxquels on ajoute des voraces divers. Des progrès sont à faire en ce domaine.

Mélange d'espèces voraces et de non voraces (forage fish) en vue d'arriver à un équilibre entre les deux, la production principale visée étant celle de voraces de qualité. La théorie de cet équilibre, plus ou moins facile à réaliser, a été développée par Swingle.

Productions successives au cours d'une année

Il y a intérêt à laisser l'étang sous eau et en état de production aussi longtemps que possible. Les méthodes de productions successives demandent des mises au point.

Productions piscicoles successives au cours d'une année.- Cette succession de productions se pratique différemment selon les climats. Dans les régions tropicales, où la durée de croissance est souvent limitée à quelques mois, on peut obtenir plusieurs productions au cours d'une année, avec les mêmes espèces et les mêmes classes d'âge. Des possibilités similaires sont offertes dans les régions tempérées chaudes, à condition d'y réduire le nombre et la durée des productions annuelles. Dans les régions tempérées froides, où les poissons ne se reproduisent qu'une fois par an, à une seule époque, on ne peut obtenir qu'une production annuelle par classe d'âge. Mais il est possible d'obtenir la production successive de diverses classes d'âge d'une seule ou de plusieurs espèces ayant des époques de reproduction différentes.

Alternance de productions animales et végétales. Au cours d'une année ou durant plusieurs années successives, il est possible de faire alterner la mise sous eau, avec culture de poissons, et l'assec, avec ou sans culture agricole (par exemple, culture du riz).

Productions simultanées, animales et végétales, dans l'étang

Elles peuvent augmenter sérieusement la production quantitative et économique.

Poissons et canards.- Une telle combinaison d'élevages présente de nombreux avantages pour la production piscicole, qui est accrue. Elle est surtout pratiquée en Europe orientale. Des essais ont été tentés en Afrique; ils demandent à être développés.

La rizipisciculture, avec culture simultanée du riz et du poisson, présente des avantages pour les deux. Surtout en honneur en Extrême-Orient, elle est très peu développée en Europe. Des essais, à développer, ont été tentés en Afrique, principalement à Madagascar.

Mollusques et crustacés.- Outre les poissons, on peut chercher à récolter des mollusques et crustacés en étangs. Cette association n'est pas développée en Europe ni en Afrique jusqu'à présent.

Elevage du ragondin.- Cet élevage, en honneur en Europe centrale et orientale et en Israël, augmente la production économique de l'étang. La production quantitative de poisson est également augmentée.

Pratique des pêches intermédiaires

Lorsque la densité de la population devient trop forte et se rapproche de la charge maximum de l'étang, ce qui se marque par un ralentissement de la production, il est souhaitable d'éclaircir les rangs de la population. La croissance des individus restants reprend et l'on peut ainsi maintenir plus ou moins longtemps l'étang à un niveau proche de sa capacité maximum.

La densité trop élevée peut résulter d'une mise en charge numérique volontairement trop élevée (poissons ne se reproduisant pas dans l'étang) ou bien d'une multiplication exagérée et non contrôlable des poissons (élevage des tilapias par classes d'âge mélangées).

La pratique des pêches intermédiaires, plus ou moins utilisée selon les régions, augmente la production quantitative. Des recherches sont nécessaires pour en préciser les modalités d'application.

Techniques spéciales de pisciculture

Lutte contre les ennemis et maladies des poissons.- Avant de chercher à intensifier la production, il faut d'abord produire des poissons sains et vigoureux (point 8 du symposium).

Sélection et élevage des prédominants.- Certaines recherches, à poursuivre, paraissent prouver que les poissons qui montrent la meilleure croissance dans leur jeune âge conserveraient cette avance ultérieurement (point 6 du symposium).

Monosexculture et culture d'hybrides d'espèces se reproduisant prématurément et trop abondamment (point 7 du symposium). Les recherches sont à poursuivre.

Monosexculture: elle a donné certains résultats positifs en Afrique, notamment avec *Tilapia nigra* au Kenya.

La culture d'hybrides, plus ou moins stériles: les meilleurs résultats ont été obtenus en Malaisie avec *Tilapia mossambica*.

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V/E-1

INFLUENCE DES SAISONS SUR LA CROISSANCE DE POPULATIONS DE TILAPIA DANS LES REGIONS D'ALTITUDE DE MADAGASCAR

par

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Résumé

Des expériences d'élevages saisonniers portant sur plusieurs espèces de Tilapia ont été entreprises à Madagascar dans deux stations de pisciculture d'altitude voisine de 1.000 mètres.

Ces expériences ont montré que la croissance d'une population de Tilapia d'une espèce donnée mais d'âges mélangés était minimum et généralement faible pendant la saison froide s'étendant de juin à août.

Par ailleurs, elles nous ont permis de vérifier que, pendant cette même période, on assistait à un arrêt complet de la reproduction.

INFLUENCE OF SEASON ON GROWTH OF TILAPIA STOCKS IN THE UPLANDS OF MADAGASCAR

Abstract

Experiments on seasonal rearing of several species of *Tilapia* were undertaken at two pisciculture stations in Madagascar located at an altitude of about 1,000 m.

These experiments showed that for a stock of *Tilapia* of a single species, but of different ages, growth was usually very poor during the cool season from June to August.

They also proved that during this period reproductive processes were at a complete standstill.

INFLUENCIA DE LAS ESTACIONES SOBRE EL AUMENTO DE LAS POBLACIONES DE TILAPIA EN LAS REGIONES ALTAS DE MADAGASCAR

Extracto

En Madagascar, en dos estaciones piscícolas situadas a una altura de cerca 1000 m se han realizado experiencias estacionales de cría de varias especies de *Tilapia*.

Estas experiencias han demostrado que el aumento de una población de *Tilapia* de una especie determinada, pero de edades mezcladas, era mínimo y generalmente escaso durante la estación fría, que se extiende de junio a agosto.

Además, esto nos ha permitido comprobar que, en este mismo período, se asiste a una interrupción completa de la reproducción.

V/E-1

1 BUT DE L'ETUDE

Le but de cette étude était de suivre l'évolution de la croissance d'une population de Tilapia en relation avec les différentes saisons. Les expériences ont été conduites dans deux stations différentes : celle de Périnet, située dans la Sous-préfecture de Moramanga sur la route Tananarive-Tamatave, à une altitude de 928 mètres et celle d'Ampamaherana située dans la Sous-préfecture de Fianarantsoa sur la ligne de chemin de fer Fianarantsoa-Tamatave, à une altitude de 1.060 mètres.

2 EXPERIENCES REALISEES

2.1 Description générale

On a réalisé, avec des mises en charge identiques, des élevages successifs, d'une durée de 3 mois chacun, correspondant toujours à une saison bien définie :

- saison chaude : décembre, janvier, février
- saison intermédiaire : mars, avril, mai
- saison froide : juin, juillet, août
- saison intermédiaire : septembre, octobre, novembre.

Chacun des élevages était poursuivi dans 4 étangs de un are. Chaque étang recevait une charge de 8 kg à raison de 2 kg de Tilapia de longueur totale inférieure à 11 cm; 4 kg de poissons moyens (longueur totale entre 11 et 15 cm) et 2 kg de gros poissons (longueur totale supérieure à 15 cm).

Les expériences se sont poursuivies durant plusieurs années.

En vue d'ajuster les rations alimentaires, des vidanges de contrôle étaient effectuées chaque mois dans un des 4 étangs, la vidange totale des 4 étangs et la fin de l'élevage intervenant après 3 mois.

Il n'a jamais été tenu compte, dans les accroissements, du poids des alevins nés au cours de l'élevage. On les a seulement dénombrés et on a noté leur longueur totale approximative.

2.2 Résultats obtenus à la station de Périnet

L'expérience, comportant 11 élevages, tous de Tilapia zillii, d'une durée de 3 mois chacun, a débuté en décembre 1959 et s'est terminée en septembre 1962.

La Figure I donne les résultats de cette expérience. Durent les 4 premiers élevages, la nourriture a été distribuée quotidiennement sous forme d'herbe, à raison du 1/10ème du poids du peuplement, ensuite, l'herbe a été distribuée à refus.

L'analyse des résultats conduit aux observations suivantes:

a) Les poids finaux des peuplements des étangs de contrôle (vidés chaque mois) sont généralement inférieurs aux poids des peuplements des autres étangs (vidés tous les 3 mois). Ceci n'a rien d'étonnant car toute vidange amène, pour l'étang, la perte presque totale du planoton et des matières minérales dissoutes dans l'eau, ainsi que la perte d'une partie de la nourriture encore dans l'étang au moment de la vidange.

b) L'influence de la saison sur la croissance des peuplements est nette : c'est en juin, juillet, août, c'est-à-dire en pleine saison froide, qu'on trouve les accroissements les plus faibles.

c) En septembre, octobre, novembre 1960, l'augmentation des poids est très importante (10,750 kg). Il est possible que cet accroissement corresponde à la période de croissance maximum de nombreux alevins nés avant la saison froide et dont la température en hausse active le développement.

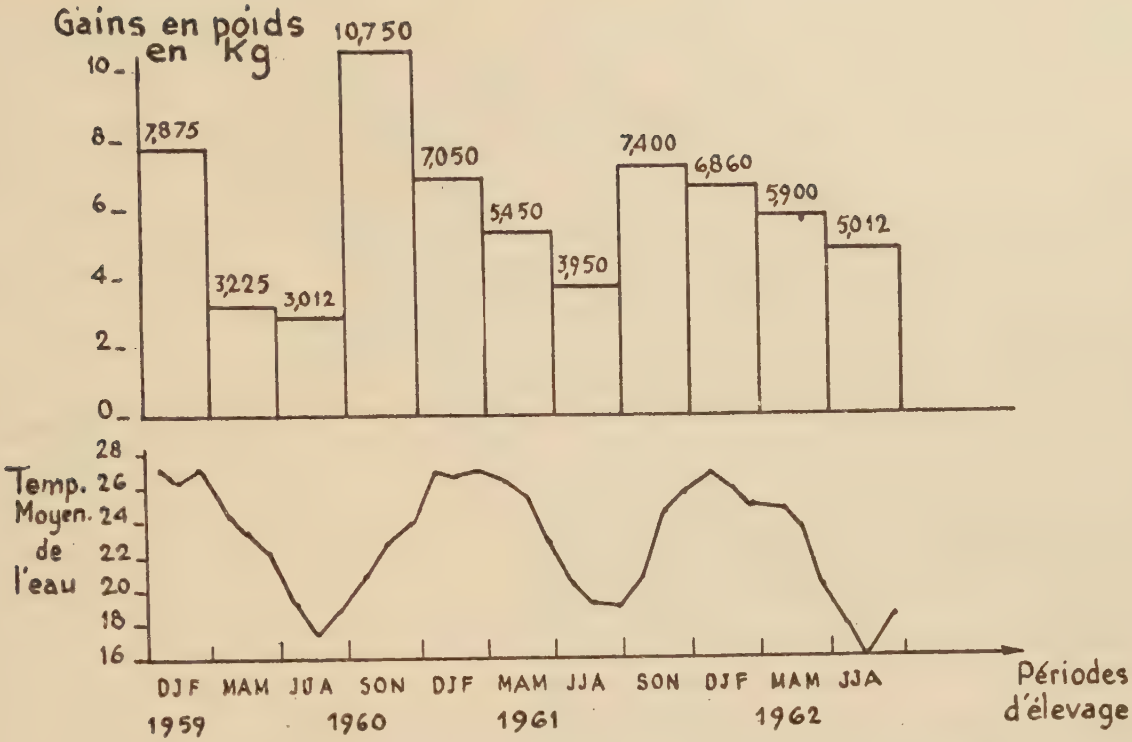

Fig. 1 Gains en poids total obtenus à Périnet dans les séries d'élevage par périodes saisonnières de 3 mois avec *T. zillii*

2.3 Résultats obtenus à la station d'Ampamaherana

Dans cette dernière station, les expériences ont débuté le 1er juin 1960 et ont pris fin en août 1963.

La première série qui s'est terminée le 1er juin 1961 a porté sur 3 espèces : *Tilapia melanopleura*, *T. mossambica* et *T. zillii*.

La deuxième série a débuté en juillet 1961 et s'est terminée en juin 1962. Cette fois les élevages portaient sur 5 espèces : *T. macrochir*, *T. mossambica*, *T. melanopleura*, *T. zillii* et *T. nilotica*.

Les résultats de tous ces élevages sont donnés aux graphiques de la Figure 2.

Ils font nettement apparaître que la période d'accroissement minimum correspond à celle de la saison froide qui va de juin à août.

V/E-1

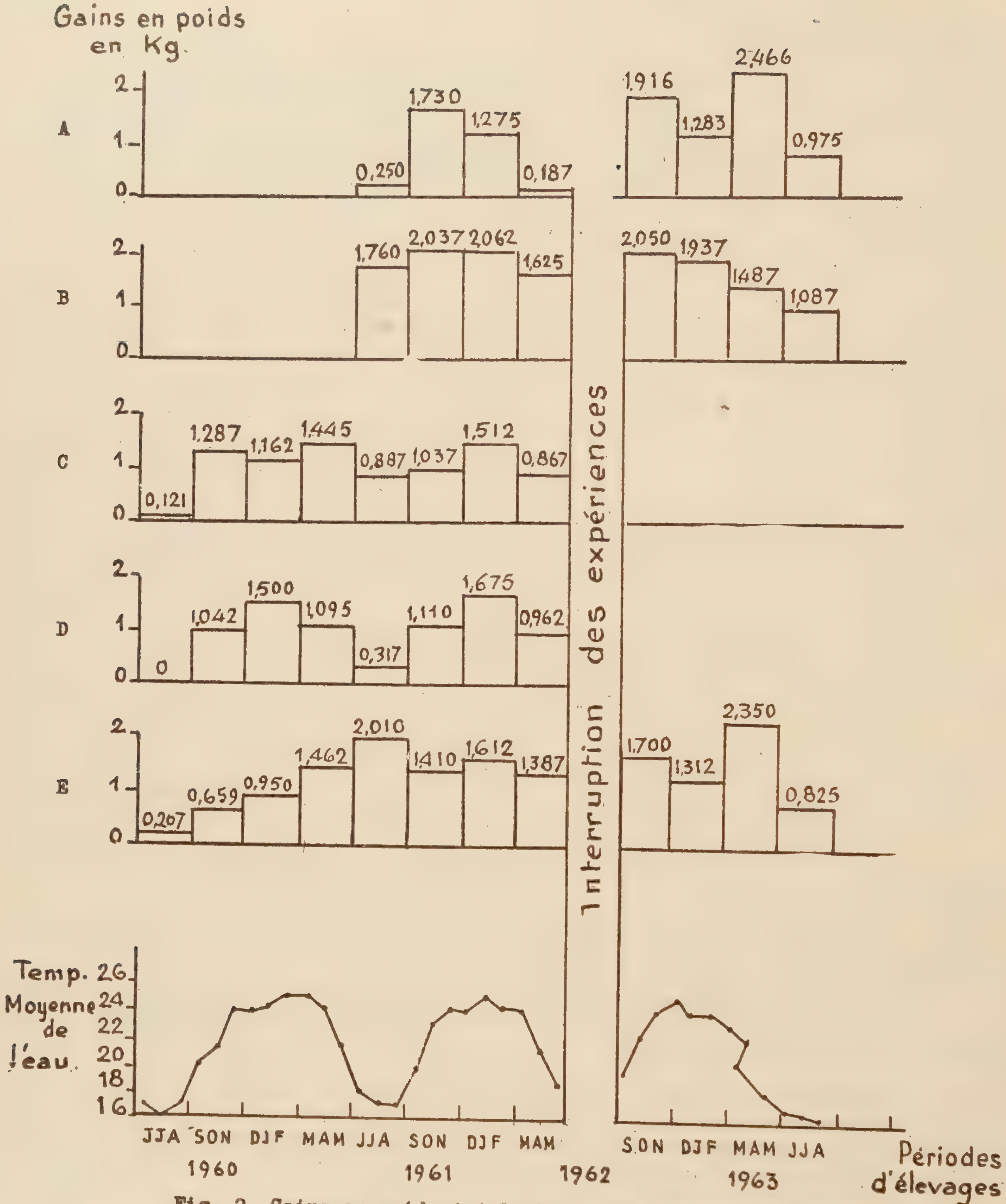

Fig. 2 Gains en poids total obtenus à Ampamaherana dans des séries d'élevage, par périodes saisonnières de 3 mois, de 5 espèces de *Tilapia*

A. *T. nilotica* B. *T. macrochir*
C. *T. zillii* D. *T. melanopleura*
E. *T. mossambica*

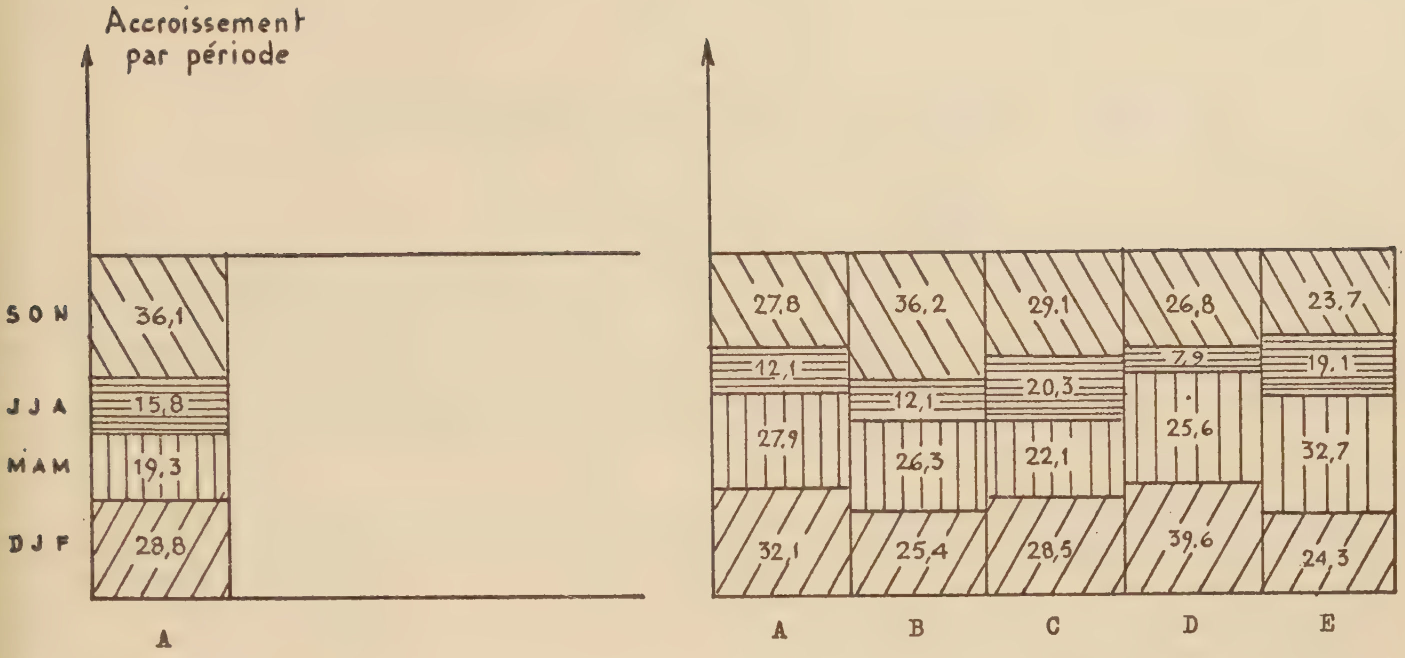

Fig. 3 Gains en pourcentage des accroissements obtenus à Périnet et à Ampamaherana aux differentes périodes saisonnières de 3 mois avec 5 espèces de Tilapia

A. T. zillii B. T. nilotica C. T. macrochir
D. T. melanopleura E. T. mossambica

3 CONCLUSION

Les divers essais d'élevage saisonniers de Tilapia entrepris à Périnet et à Ampamaherana montrent clairement que, dans ces deux stations, la période de saison froide allant de juin à août correspond à celle durant laquelle l'accroissement en poids est minimum.

Les comptages effectués permettent également d'affirmer que, pendant la saison froide, la production d'alevins est nulle.

La différence entre l'accroissement de saison froide et les accroissements des autres saisons est encore plus accentuée que ne l'indiquent les figures car, si nous tenons compte de la fonction de reproduction, nous pouvons dire qu'en juin, juillet et août, toute la ration alimentaire est utilisée pour le métabolisme d'entretien et pour la croissance, alors qu'au cours des autres périodes, la ration sert également à assurer la fonction de reproduction et c'est ainsi qu'en élevage monosexe, par exemple, nous aurions des accroissements bien plus importants que ceux indiqués par les figures, d'autant plus que les alevins sont également des consommateurs et donc des concurrents.

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V/E-2

TEMPERATURE AND YIELD IN CARP PONDS

by

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Abstract

Data collected at a fish farm near Warsaw, Poland, were analyzed to find a quantitative measure of the effect of temperature on carp production. Average water temperatures for the period July-August correlated well with the production due to natural food; better correlation was found between the number of warm days when temperature reached 20°C or more and the production. One warm day brought about an increase of carp yield by 4 to 4.7 kg per ha depending on rearing conditions.

These results may be explained by the pattern of carp growth during the rearing season and the concept of thermic preference and related phenomena.

DE L'INFLUENCE DE LA TEMPERATURE SUR LE RENDEMENT EN CARPICULTURE

Résumé

Les données recueillies sur une exploitation piscicole près de Varsovie (Pologne) ont été analysées pour obtenir une mesure quantitative de l'incidence de la température sur la productivité des carpes. On a constaté une bonne corrélation entre les températures moyennes de l'eau pendant la période juillet-août et la production due aux aliments naturels; la corrélation la plus satisfaisante a été établie entre le nombre de jours chauds où la température de l'eau atteignait 20° ou davantage et la production. Au cours d'une journée chaude, on a noté une augmentation de la production des carpes de 4 à 4,7 kg par ha, selon les conditions d'élevage.

Ces résultats peuvent s'expliquer par la structure de la croissance de la carpe pendant la période d'élevage ainsi que par le concept de la préférence thermique et les phénomènes connexes.

TEMPERATURA Y RENDIMIENTO EN LOS ESTANQUES PARA CARPAS

Extracto

Se analizaron los datos recogidos en una piscifactoría cercana a Varsovia (Polonia) para encontrar una medida cuantitativa del efecto de la temperatura sobre la producción de carpas. Las temperaturas medias del agua durante el período julio-agosto correspondieron bien con la producción debido a la alimentación natural; se halló una correlación aún mayor entre el número de días cálidos en que la temperatura llegó a 20°C o más y la producción. Un día cálido determinó aproximadamente un aumento del rendimiento de carpas de 4 a 4,7 Kg por hectárea según las condiciones en que se criaban aquéllas.

Estos resultados pueden explicarse por las características del crecimiento de la carpa durante la temporada de desarrollo y el concepto de preferencia térmica y fenómenos conexos.

1 INTRODUCTION

Experienced carp culturists claim that the temperature during the growing season, varying from year to year, has a considerable effect on carp yield. Little, however, has been done to find out any quantitative measure of this effect.

Juniewicz (1938) made an attempt to relate average air temperatures of the growing season between March and September to carp yields in two farms in Lithuania. He found that an increase of average temperature of 1°C resulted in yields increased by 20 or 36 kg per ha in one farm. The effect of water temperature on the yield of carp was analyzed by Stegman (1960) and then by Backiel (1964). This report is a revised version of these two papers and includes some explanation of our findings.

2 SOURCE OF DATA

We have availed ourselves of the data collected at the fish pond-farm, Laki Jaktorowskie, near Warsaw, Poland. The data consisted of daily records of temperature measurements during the growing season (April-September) and of records of the weights and numbers of second-year fish stocked every spring and removed every autumn, and the amount of supplementary feeds given to fish during the growing season.

Temperature of water was measured at 0800 hr, 20 cm below the surface. The temperature is probably somewhat below average daily temperature, since minimum usually occurs after sunrise and maximum in the afternoon (between 1300 and 1600 hr) (Szumiec, 1964).

3 AVERAGE TEMPERATURE OF WATER AND CARP PRODUCTION

Assuming that temperature affects the natural food resources of the pond and that production of carp is due to these resources, Stegman (1960) applied a simple model for calculating the production, viz.

$$P_n = N_k (\bar{w}_k - \bar{w}_o) - K/5 \qquad (1)$$

P_n - production due to natural food, kg/ha

$K/5$ - amount of fodder given per season and per ha divided by food conversion factor = 5

N_k - number of fish per ha removed in autumn

$\bar{w}_o$, $\bar{w}_k$ - average weight of carp at stocking (spring) and at catching (autumn) respectively

The food conversion factor 5, is in common use for fish culture in Poland while feeding carp with leguminous seeds, rye and barley, as was the case at the fish farm considered here.

The average production (P_n) for five ponds over a six-year period and the average temperatures are given in Table I. Considering the whole period, or each month separately, only July and August temperatures correlate with the production. An even stronger correlation exists between production and average temperature of the July-August period.

The regression equation obtained for this period

$$P_n = 49.5\ \bar{T}_{JA} - 697.2 \qquad (2)$$

means that an increase of average temperature of 1°C brought about a production increase by nearly 50 kg/ha ($\bar{T}_{JA}$ - average temperature of water in July and August).

Table I

Carp production due to natural food (kg/ha) and average temperature of water (°C). Production values arranged in an increasing series, (data from Stegman, 1960).

Av. production due to natural food	Average temperature of water in month of:						in the period:			Year
	April	May	June	July	Aug.	Sept.	July-Aug.	June-Aug.	April-Sept.	
179	7.0	13.2	19.3	18.9	16.7	13.8	17.8	18.3	14.7	1956
216	4.7	14.6	20.9	18.5	18.8	15.2	18.7	19.4	15.4	1954
241	9.5	12.4	19.1	20.0	17.2	12.0	18.6	18.7	15.1	1957
266	8.0	14.7	20.5	21.2	17.8	13.8	19.5	19.8	16.0	1953
292	10.1	12.7	17.0	19.8	19.5	11.5	19.7	18.8	15.1	1952
358	4.8	12.7	17.6	21.6	21.2	16.1	21.4	20.1	15.7	1955
	Correlation coefficients between production and temperature of the period									
			no	0.816^{x}	0.868^{x}	no	0.982^{xx}	0.681	no	

N.B.

x - significant at 0.05 probability level xx - significant at 0.01 probability level

Table II

Carp production due to natural food and number of days when temperature of water was above 16°C, 18°C, 20°C or 22°C. (Data from Stegman).

Average production kg/ha	Number of days when temperature was at least:							
	16°C		18°C		20°C		22°C	
	in the period							
	April-Sept.	July-Aug.	April-Sept.	July-Aug.	April-Sept.	July-Aug.	April-Sept.	July-Aug.
179	98	56	54	29	34	15	13	4
216	119	61	91	45	47	20	10	3
241	98	55	67	37	44	27	12	9
266	104	60	85	49	61	33	34	12
292	97	59	63	49	42	38	14	14
358	102	62	92	62	77	58	30	26

The relationship holds true within a small range of temperatures, viz. between 17.8 and 21.4°C, and any extrapolation may even lead to absurd results.

4 NUMBER OF WARM DAYS AND CARP PRODUCTION

Stegman (1960) applied another measure of the action of temperature exerted on carp growth namely the number of warm days, i.e. days on which water reached temperatures above a certain level. Four such levels were analyzed: 16, 18, 20 and 22°C. Here again, as in case of average temperatures, the best correlation was sought. Keeping in mind that the period of July and August was found to affect production most significantly this period as well as the whole growing season is also shown in Table II.

Attention should be drawn to the fact that the higher the temperature taken as minimum to designate a day as warm, the better the numbers of warm days correlate with production. The best correlation was found between the number of days in July and August with minimum temperature of 20°C.

The correlation coefficient in this case was 0.992, thus higher than that between average temperatures in the same period and production figures.

Taking all 30 observations, i.e. five ponds during six years separately, this correlation coefficient was 0.8272 and regression equation was:

$$P_n = 4.0641 \times D_{T>20} + 128.6 \qquad (3)$$

where P_n - as before, $D_{T>20}$ - number of days with temperature at least 20°C.

In other words one day in which water reached a temperature of 20°C or more in July or August increased production due to natural food in the five ponds of the farm considered here by about four kg per ha. The sum of daily temperature above 20°C in this period correlated well with production, but not better than did the number of warm days (Stegman, 1960).

The period between 1 July and 31 August, taken somewhat arbitrarily, may raise reservations. However, including June or the last 10 days of it as well as excluding the first 10 days of July from that period, resulted in a significantly worse correlation.

5 SIMULTANEOUS CALCULATION OF FOOD AND THERMIC COEFFICIENTS

Models of the relationship between carp production and temperature involve assumptions that the food conversion factor is five and that density of carp did not affect its growth. In order to prove the assumptions, a multiple regression method was applied (Backiel, 1964).

A model accepted for calculations can be expressed by a formula:

$$P = b_1 D + b_2 K + b_3 N + a \qquad (4)$$

where:

P - total production of carp per ha

K - amount of food given per ha

N - number of fish per ha

D - number of warm days

b_1, b_2, b_3 - respective regression coefficients

Keeping in mind that only high temperatures in July and August showed significant correlation with carp production, numbers of days on which water reached a temperature of 20°C or more in this period were taken into consideration. The data were collected from the same farm but included only three ponds and nine years between 1952 and 1960. Since the years when carp mortalities in some ponds reached 20 percent or more were excluded, the total number of sets of variables amounted to 22.

An analysis of variance (Table III) shows that the effect of carp density on production is insignificant, in spite of rather large variation of the former, viz., between 485 and 1,027 fish per ha. It is probably connected with the correlation between stocking rate and amount of fodder per ha which is quite strong and equal to 0.776. Production was, however, well correlated with the number of warm days and with the amount of fodder.

Partial correlation coefficients:

$$r_{PK\,.\,T} = 0.7995^{xx}$$

$$r_{PT\,.\,K} = 0.8639^{xx}$$

showed that production was better correlated with the number of warm days than with the amount of food.

Regression equation:

$$P = 4.6766\ T + 0.3032\ K + 34.9 \qquad (5)$$

means that one warm day increased production by about 4.7 kg/ha and one kg of fodder raises yield by 0.3032 kg. The latter coefficient, which may be expressed as food conversion factor = 3.3, differs significantly from that taken for previous calculations i.e. 5.

The coefficient 4.7 is also significantly different from the coefficient obtained by Stegman (1960) viz., 4.06 kg/ha per warm day.

This difference, however, cannot be attributed to various food factors. Applying the first model [equation (1)] to calculate regression from the set of data which were taken for multiple regression calculation we arrive at:

$$b_1 = 4.6483$$

practically = 4.6766 as before [equation (5)].

Thus the error involved in the assumption that food conversion factor was equal to five did not affect the result regarding the thermic coefficient.

The difference between the result arrived at by Stegman (1960) and the result of Backiel (1964) i.e. between the thermic coefficients 4.06 and 4.68 is therefore associated with the sets of data that were different; Stegman (1960) used data from five ponds throughout the period 1952 to 1957; Backiel (1964) took data from three ponds out of the five and the period included three years more.

6 DISCUSSION

Temperature effects on carp metabolism and behaviour may offer some explanation of the results of our analysis. The fish is polythermic; it spawns usually in Poland at 18°-20°C. A "wild" carp in natural waters spawns at 17°C (Kryzhanovski, 1949). Upper lethal temperature is high. Black (1953) found that carp acclimatized at 20°C had 50 percent mortality at 35.7°C and 100 percent at 36.9°C. Shkorbatov's (1964) estimates show an even higher limit viz., 39°C for fingerlings checked in July.

Table III

Analysis of variance of regression: production of carp (P) versus amount of food (K), number of warm days (T) and stocking rate (N)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	21	166 737	
Regression on K, T, N	3	142 439.49	
Regression on K, T	2	140 710.28	70 355.14 xx
Due to N after the effect of K and T has been discounted	1	1 729.21	1 729.21
Due to T after K	1	89 008.26	89 008.26 xx
Due to K after T	1	54 806.00	54 806.00 xx
Deviations from regression on K, T	19	26 026.72	1 369.80

Table IV

Temperatures preferred by carp

Size or age of fish	Acclimatization temperature	Preferred temperature	Source
3-4 cm	room temperature	21.3°C	Schmeing-Engberding, 1953
14 days	6-7°C (for 2 days)	16-17°C	Mantelman, 1958a
1 month	6-7°C (for 2 days)	17-23°C	
1 month	12-15°C (for 2 days)	19-23°C	
2 month	12-15°C (for 2 days)	19-23°C	
from hatching until 70th day	unknown	23-27°C	Mantelman, 1958b
	Final preference		
unknown	32°C	32°C	Pitt, Gerside Hopburn, 1950, in Alabaster, 1964

Carp prefer a rather high temperature when they have a choice. Thermal preferences shown in Table IV were higher than acclimatization temperatures; the final preference, when the temperature selected is equal to acclimatization temperature, is quite high. Schmeing-Engberding (1953) found that the rate of oxygen consumption increased with rising temperature but the relationship did not follow the simple exponential Krogh's curve; there was a plateau for temperatures between 21° and 25°C. This range included the preferred temperature.

Oya and Kimata (1938) studied the same relationship but did not mention any plateau. However, examining their figure 6b - oxygen consumption of carp in standing water - one can detect that between 15° and 20°C the rate of oxygen consumption remained at practically the same level.

Thus, the effect of temperature on metabolism is rather complicated and so is its effect on growth. Within the preferred range of temperature carp evince greatest appetite and, most probably, maximum growth rate. Shpet (quoted by Mantelman. 1958b) found that daily food consumption in carp was greater at 23 to 27°C, which was the preferred temperature (Table IV), than at 16 to 18°C and at 29 to 30°C.

In view of these findings the model accepted by Stegman (1960) and Backiel (1964), where the effect of temperature and the effects of feeding on growth and thus on production were considered separately, is somewhat over simplified. Obviously temperature affects intake and conversion of both natural food and agricultural feeds. Total production of carp is a function of the amount of the two kinds of food regarded as functions of temperature.

However, it should be stressed that feeds were distributed in such a way during the feeding season, that the amount of food given per unit of time was positively correlated with temperature in these units. This is the usual procedure in feeding carp. Thus, the role of temperature in this case is already taken into account.

It has been found that only high temperatures in July and August correlated with production. Why did, however, temperatures of June which were equally high not affect the whole-season weight increase? This may be explained by the growth pattern of carp in ponds. In June the carp were small, hence the effect of temperature in this month on rate of fish growth was smaller than the effect in the two succeeding months, the period of fastest growth when carp gained about 60 or even 80 percent of the whole-season increment in weight (Gurzeda, 1957).

The acclimatization process may be of some importance in the pattern of growth. June was the first warm month in the growing season but it takes some time for the fish to adjust its metabolism to a higher temperature. While acclimatizing, the fish does not grow as well as after it has been acclimatized.

Bearing in mind that within preferred temperatures the fish metabolism does not change, the length of the preferred temperature period has to be taken into account when considering growth increments. Since the preferred range of temperatures lies around 20°C, the number of warm days with 20°C temperature had the most significant influence on the growth increment of carp and on production. The average temperature of July and August and the sum of daily temperatures above 20°C were in fact other measures of the length of the preferred temperature period and, therefore, they also correlated well with carp production.

The magnitude of the effect of preferred temperature duration on carp production depends on actual rearing conditions; the thermic coefficients: 4 kg/ha/warm day or 4.7 kg/ha/warm day - differed on the grounds of various sets of basic data.

The coefficients cannot be applied to other carp pond farms without reservations. However, they make it possible to forecast the production of carp at Laki Jaktorowskie farm in the first days of September and both equations (3) or (5) will give a sufficiently good approximation, if the stocking and feeding rates do not exceed those taken for calculating regression equations, and the kind of fodder is the same as before.

The general conclusion is that in cool temperate climates and where about 50 percent of carp production is due to natural food resources, the effect of the temperature on production is highly significant. Year-to-year variations of temperatures may be responsible for considerable variations in yield of carp in ponds.

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PROCEDURES FOR OVERWINTERING TILAPIA

by

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Abstract

This paper deals with the methods used in overwintering large numbers of tilapia indoors. The facilities, stocking procedure, feeding and care of fish, treatment for parasites, and cost are reported.

TECHNIQUES UTILISEES POUR L'HIVERNAGE DES TILAPIAS

Résumé

Cette communication traite des techniques utilisées pour l'hivernage à l'intérieur d'un grand nombre de tilapias. Elle contient des renseignements sur les installations, les techniques de stockage, l'alimentation et les soins à donner aux poissons, les traitements antiparasitaires et le prix de revient.

PROCEDIMIENTOS PARA MANTENER LA TILAPIA DURANTE EL INVIERNO

Extracto

Se ocupa esta monografía de los métodos utilizados para mantener durante el invierno a grandes cantidades de tilapia en locales cerrados. Se describen las instalaciones, procedimientos de repoblación, alimentación y cuidado de los peces, tratamiento de parásitos y costos.

1 INTRODUCTION

Tilapia are potentially valuable pond fishes in the United States because of their rapid growth, high production, efficient food conversion, and herbivorous nature. One of the problems encountered when using these fish is their inability to survive water temperatures below 12°C. Consequently, large numbers of tilapia must be overwintered indoors for the following year's research. This paper summarizes methods developed for overwintering tilapia at Auburn.

2 OVERWINTERING FACILITIES

Tilapia are held in 272-litre wood troughs, 2.4 m x 0.6 m.

Stream water is limed to a pH of 7. Suspended material in the water is removed by floculation with aluminum sulphate and filtration through gravel and sand. The water flows by gravity to each trough and affords a complete change every two to five hours. Water temperature is maintained near 21°C by utilizing a mixing valve to combine cold water and water heated by a 600,000 BTU fuel-oil furnace.

3 STOCKING PROCEDURES

Tilapia are moved into a heated building in early October where they are held 24 hours in concrete tanks to allow the fish to void themselves of faeces. They are anesthetized with 250 ppm of M.S. 222 (tricaine methanesulphonate) for ease in handling. Tilapia are then sorted to size, weighed, dipped for 15 seconds in 1 ppt acriflavine and stocked in troughs that were previously disinfected with a commercial solution of five percent sodium hypochlorite. Sixty brood tilapia are stocked per trough, while fingerling fish are stocked at 11.34 kg, averaging 2,000 fish per trough.

Tilapia mossambica and T. nilotica sometimes become extremely nervous when first stocked into troughs. They swim excitedly back and forth and often dash onto the sides of troughs. This activity usually ends with the fish swimming on its side in tight circles and finally coming to rest on the bottom in an apparent state of tetany. Most affected fish never recover from the shock, and a few attacks of this "mass hysteria" can kill all fish in a trough. No explanation has been found for this phenomenon; the fish have shown no significant parasite infestation or disease.

4 CARE OF FISH

Tilapia are fed daily one percent of their bodyweight six days a week with a commercial pelleted feed.

Troughs are cleaned at two-week intervals and flush treated with two to four ppm PMA (pyridylmercuric acetate) as a prophylactic.

Parasites and diseases become a problem under the crowded conditions in the troughs. This problem is magnified when the water temperature drops to near 14°C because of occasional furnace failure. Usually T. mossambica and T. melanopleura develop a severe case of fin rot although T. nilotica are not affected. A gram negative rod bacterium was found which appeared to be the causative agent. Good control is obtained when the fish are treated with two ppm PMA as a static treatment for one hour.

Trichodina sp. and Chilodon sp. are also a problem, but are controlled with 250 ppm formalin as a static treatment for one hour.

Saprolegnia sp. is sometimes a secondary invader and is controlled with 1 ppm malachite green as a flush treatment or eight ppm KM_nO_4 as a static treatment for one hour.

5 COST OF OVERWINTERING TILAPIA

The cost of overwintering tilapia during the winter of 1959-60 is itemized below:

Item	
Labour (feeding, cleaning troughs etc. 360 hours at $1.00 per hour)	$360.00
Heat (3,100 gallons fuel oil at 13 cents a gallon)	403.00
Food	115.00
Electricity	360.00
Total	$1,238.00

These cost figures are somewhat misleading since the facilities were operated throughout most of the winter at less than one-half capacity because of heavy losses of fish from shock. The $1,238 was the cost of overwintering approximately 25,000 tilapia. The cost per thousand fish was $49.52. If the facilities had been kept at capacity, the cost might have been only one-third, or $16 per thousand fish.

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V/E-4

METHODES AMELIOREES D'ELEVAGE DES CARPILLONS D'UN ETE POUR ACCROITRE LA PRODUCTION DES ETANGS DE CARPICULTURE

par

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4 RESULTATS OBTENUS EN 1964 350

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Résumé

Pour répondre aux besoins croissants de la demande les éleveurs yougoslaves se trouvaient devant un dilemme: soit consacrer une plus grande partie des étangs à la production de carpillons d'un été aux dépens des superficies destinées à la production de poisson marchand, soit trouver des techniques améliorées pour intensifier la production de carpillons d'un été. L'Institut de pisciculture en eau douce de Zagreb donc était chargé d'effectuer des expériences en vue d'intensifier les méthodes de production de carpillons d'un été.

De nouvelles méthodes de carpiculture assurant des rendements très élevés ont été essayées avec succès. Elles sont basées sur une culture intensive de carpillons de bonne qualité dans un espace restreint au minimum. Les rendements sont passés de 780 kg/ha à 1 500 - 1 600 kg/ha et dans certains cas à 2 000 - 2 500 kg/ha. Il est nécessaire cependant de traiter avec soin les étangs destinés à la production de carpillons. La fumure régulière assure une production organique naturelle constante. On peut obtenir de bons résultats sans utiliser de concentrés ni ajouter de vitamines, d'antibiotiques ou d'oligo-éléments à la nourriture. Celle-ci doit être riche en protéines. La méthode du frai artificiel ou naturel et l'emploi du système complet ou incomplet de Dubisch ont peu d'influence sur les rendements.

V/E-4

IMPROVED METHODS OF RAISING "SUMMERLINGS" FOR INCREASED PRODUCTION FROM CARP PONDS

Abstract

The Yugoslav fish farmers had to make a choice between increasing pond area under "summerling" production at the expense of areas used for the production of marketable fish and devising improved and intensive techniques of "summerling" production, to meet increasing demand. The Freshwater Fish Culture Institute at Zagreb carried out experiments to intensify "summerling" production methods.

New carp culture methods were tried successfully and they were found to provide very high yields. They are based on the intensive culture of "summerlings" of good quality in the minimum area required. Yields were increased from 780 kg/ha to 1,500-1,600 kg/ha and in certain cases to 2,000-2,500 kg/ha. It is necessary, however, to take good care of the ponds used for "summerling" production. Regular manuring gives a natural and constant organic production. Good results can be obtained without concentrates, without adding vitamins, antibiotics or micro-elements to feeds. Feeds must be rich in protein. The artificial or natural method of spawning, or the use of the complete or incomplete system of Dubisch have little effect on yields.

METODOS MEJORADOS DE CRIA DE JARAMUGOS PARA AUMENTAR LA PRODUCCION EN LOS ESTANQUES DE CARPAS

Extracto

Los piscicultores yugoeslavos tuvieron que decidir entre aumentar la superficie dedicada a la cría de jaramugos a expensas de la dedicada a la producción de peces comerciales, o idear técnicas intensivas y mejoradas de producción de jaramugos con objeto de satisfacer la creciente demanda. El Instituto de Piscicultura de Agua Dulce de Zagreb realizó experimentos para intensificar los métodos de producción de jaramugos.

Se probaron con éxito nuevos métodos de cultivo de carpas, encontrándose que proporcionaban rendimiento muy elevados. Tales métodos se basan en el cultivo intensivo de jaramugos de buena calidad en la superficie mínima requerida. Los rendimientos aumentaron de 780 kg/ha a 1.500-1.600 kg/ha y en ciertos casos a 2.000-2.500 kg/ha. Sin embargo, es necesario dedicar gran atención a los estanques empleados para la producción de jaramugos. El abonado regular proporciona una producción orgánica natural y constante. Se pueden obtener buenos resultados sin concentrados, sin añadir vitaminas, antibióticos o microelementos a los piensos. Los piensos deben ser ricos en proteínas.
El método natural o artificial de desove, o el empleo de un sistema completo o incompleto de Dubisch ejercen poca influencia en los rendimientos.

1 INTRODUCTION

Il y a cinq ou six ans que les carpiculteurs yougoslaves ont abandonné les anciennes méthodes dans le processus technologique de l'élevage des carpes, tandis que la plupart des pays européens les appliquent toujours. Les nouvelles méthodes introduites à leur place assurent des rendements beaucoup plus élevés. Les essais ont montré qu'en appliquant ces méthodes qui consistent en plus grande densité des feuilles par unité de superficie, ensuite en alimentation plus intensive de fourrage de bonne qualité et en fumure rationnelle de l'étang, les rendements par unité de superficie de l'étang peuvent devenir, dans nos régions, doubles ou même triples. Cela veut dire que la moyenne yougoslave de l'élevage de la carpe en étang peut s'élever de 780 kg/ha en 1959 à 1.500-1.600 kg/ha, et dans les cas particuliers où l'élevage se fait dans les conditions meilleures, à 2.000 - 2.500 kg/ha. Si l'on tient compte de la valeur du poisson comme source de protéines pouvant remplacer la viande de boucherie, en déficit constant, cet accroissement du rendement est un résultat remarquable.

Cependant, passant à une telle méthode de la production intensive de carpe à consommer, toute une série de problèmes sont apparus dont le plus important est celui de la production de quantités suffisantes de feuilles de qualité.

La production des alevins d'un an ou feuilles, est la base de la production de l'élevage du poisson en étang, et dans les conditions où les rendements sont élevés, ce problème s'aggrave encore plus. Pour obtenir ces rendements élevés il faudrait produire une quantité double ou même triple de feuilles. En outre pour une telle production la feuille ne devrait pas avoir un poids inférieur à 50 g sinon on ne pourrait pas obtenir une production très élevée ou bien la qualité du poisson ne répondrait pas aux exigences du marché européen.

Les carpiculteurs yougoslaves se sont donc trouvés devant un dilemme, agrandir les superficies des étangs pour la production de la feuille ou bien trouver quelques nouvelles méthodes dans l'élevage de la feuille, afin que cet agrandissement des superficies pour la production de la feuille ne tourne pas au désavantage des superficies destinées à la production du poisson à consommer et ne nécessite pas de nouveaux investissements. Ce problème étant devenu le problème le plus aigu dans la production de l'élevage de la carpe en étang en Yougoslavie, nous nous sommes mis tout de suite à chercher sa solution. L'Institut pour la Pisciculture en eau douce à Zagreb a élaboré les programmes des essais et ces essais ont été effectués dans les étangs de l'Institut destinés aux expériences et sur quelques autres économies pour la carpiculture en 1962, 1964 et 1965.

Le poisson n'étant pas encore tout recueilli dans les étangs d'essai au moment où j'écrivis ce rapport et par conséquent tout le matériel n'étant pas encore trié et élaboré, il ne m'est pas possible de donner les résultats des essais de 1965, bien que les observations que nous avons eu jusqu'à présent, nous font espèrer un succès extraordinaire. Je vais essayer d'éclaircir ce problème en vous présentant les résultats et les observations de 1962 et 1964 et d'en tirer certaines conclusions.

2 DESCRIPTION ET BUTS DES EXPERIENCES

En 1962, à l'occasion de l'essai qui a été effectué sur une économie pour la carpiculture, on a reçu la feuille du frai artificiel des carpes reproductrices et l'élevage ultérieur s'est poursuivi suivant le système complet de Dubisch. Dans l'étang de notre Institut destiné aux expériences on a reçu la feuille du frai naturel dans les étangs d'alevinage et le procédé ultérieur s'est développé selon le système incomplet de Dubisch (l'étang à pose - l'étang d'empoissonnement appelé encore l'étang de 1er été). On a fait ces expériences en premier lieu parce que la plupart des étangs de Yougoslavie n'ont pas encore un système complet pour la production de la feuille, et la valeur pratique de cet essai est d'autant plus importante.

Le but de ces expériences était :

- de reproduire, à partir d'un groupe de carpes (une carpe femelle et deux carpes mâles) au moins 100.000 alevins de 5 à 10 jours, aptes à l'élevage ultérieur;

- de reproduire selon le système complet de Dubisch, 200.000 carpillons C_0/ha, d'environ 0,8-2 g, dans l'étang où l'on élève pendant un mois la feuille déposée de l'étang à pose, pour l'introduire ensuite dans l'étang de 1er été.

- de reproduire dans un étang de 1er été, 2.000 kg de carpe feuille C_1, d'environ 50-100 g, qui servira pour la reproduction dans la saison d'élevage suivante.

Nous avons supposé pouvoir obtenir ce but en appliquant les mesures suivantes :

- désinfecter avant usage avec la chaux vive (2.000 kg/ha) tous les étangs destinés à l'élevage;

- préparer 140 reproducteurs pour la production de la feuille et leur enlever les hypophyses pour le frai artificiel;

- élaborer et mettre à l'essai le nouveau type de tamis plastiques;

- après avoir déposé les alevins dans l'étang de 1er été, les nourrir exclusivement avec de l'orge, du lupin, des vitamines et des antibiotiques. Le coefficient de la nourriture doit être environ 2;

- l'étang de 1er été doit être régulièrement fumé par des engrais minéraux, à plusieurs reprises au cours de l'élevage (tous les 15 jours, 50 kg/ha de superphosphate et 20 kg/ha de sulfate d'ammonium.

On a commencé dès le mois de février à préparer des étangs pour l'élevage et à les désinfecter. Le frai a été effectué au mois de mai, ainsi que le déplacement des alevins dans l'étang où ils restent pendant (économie pour la carpiculture), respectivement dans l'étang de 1er été (Institut). Ensuite on nourrit le poisson jusqu'à la fin du mois d'octobre et on fait la fumure régulière de l'étang.

Sur l'économie pour la carpiculture on a utilisé pour les essais deux étangs de 1er été A et B de 3,5 et 7 ha, et sur l'étang de l'Institut destiné aux essais, l'étang N° III de 5,5 ha.

Le programme a été effectué en totalité, excepté les préparations de vitamines et d'antibiotiques (VAM) qui n'étaient pas ajoutées à l'alimentation sur les étangs destinés aux expériences.

3 RESULTATS OBTENUS EN 1962

3.1 Economie pour la carpiculture

On a obtenu de 7 carpes femelles 2.120.000 oeufs. La fertilité s'élevait à 84 pour cent et les pertes des alevins jusqu'à huit jours s'élevaient à 40 pour cent, ce qui veut dire qu'on a obtenu 1.272.000 alevins âgés de huit jours.

On a empoissonné l'étang de 1er été A avec 170.000 carpillons, et l'étang de 1er été B avec 550.000 carpillons.

La Commission a organisé une pêche le 29, le 30 et le 31 octobre 1962 et les résultats obtenus étaient les suivants :

Etang de 1er été A

On a attrapé 66.913 carpillons C_1, soit 19.118 carpillons/ha. L'accroissement total s'élevait à 7.293 kg ou 2.083 kg/ha.

Le poids moyen du carpillon était : 108 g
Le coefficient de nourriture : 3,2

Etang de 1er été B

On a attrapé 130.000 carpillons C_1, soit 17.394 carpillons/ha. L'accroissement total s'élevait à 11.622 kg, soit 1.549 kg/ha.

Poids moyen du carpillon : 89 g
Coefficient de la nourriture : 2,3

La production moyenne dans les deux étangs de 1er été s'élevait donc à :

Nombre total de carpillons :	197.373
Poids total :	18.915 kg
Poids moyen par carpillon :	96 g
Production moyenne par hectare :	1.801 kg
Coefficient moyen de nourriture :	2,45

Les carpillons étaient en bonne santé, bien engraissés, et avaient une forme exceptionnelle.

3.2 Institut

Le frai a été effectué dans l'étang à pose le 7 mai 1962. D'une carpe femelle (d'une garniture) on a obtenu 120.000 alevins âgés de 8 jours.

On a mis 250.000 alevins environ de 1 à 2 cm de longueur dans l'étang de 1er été.

La Commission a organisé la pêche le 26 octobre 1962 qui a donné les résultats suivants :

On a attrapé 197.600 carpillons C_1 d'un poids total de 11.856 kg soit 35.916 carpillons ou 2.155 kg/ha.

Poids moyen du carpillon : 60 g
Coefficient de la nourriture: 2,18

La feuille était en bonne santé, bonne condition, bien engraissée, avait une belle forme et était apte à la reproduction ainsi qu'à obtenir les rendements élevés.

Pour certaines raisons ces essais ne furent pas effectués en 1963 mais ils furent poursuivis en 1964.

4 RESULTATS OBTENUS EN 1964

4.1 Economie pour la carpiculture

Cette année la fertilité était considérablement plus haute et s'élevait à un taux de 90-95 pour cent (frai artificiel).

Le 27 mai 1964 l'étang de 1er été B a été empoissonné avec 900.000 feuilles soit environ 120.000 feuilles/ha.

Les 27 et 29 mai on a empoissonné 6 étangs d'élevage avec 87.180 feuilles (300.000 feuilles environ par hectare). Ces feuilles ont été récoltées le 23 juin et le poids moyen de la feuille était de 0,82 g. On a récolté au total 75.624 feuilles et on les a déposées ensuite dans l'étang de 1er été A.

Les feuilles ont été traitées au cours de la saison d'élevage de la même manière qu'en 1962; la pêche a été effectuée le 15 novembre 1964 et donna les résultats suivants :

Etang de 1er été A

On a attrapé 60.000 carpillons C_1 d'un poids total de 3.461 kg, soit 17.142 carpillons ou 988 kg/ha.

Poids moyen : 57 g
Coefficient de nourriture : 2,40

Etang de 1er été B

On a récolté 88.733 carpillons C_1 d'un poids total de 7.724 kg soit 15.549 carpillons ou 1.103 kg/ha.

Poids moyen : 87 g
Coefficient de nourriture . 2,30

La production moyenne de cet étang s'élevait alors, en 1964, à 1.065 kg/ha. La feuille était, cette année aussi, en bonne santé et bien engraissée.

4.2 Institut

Les carpes femelles ont été mises dans l'étang à pose dans la première moitié du mois de mai et les résultats du frai furent exceptionnels.

150.000 feuilles sont ensuite déposées dans l'étang de 1er été N° III où on les nourrit et on fait la fumure de l'étang de la même manière qu'en 1962.

La pêche a été effectuée les 3 et 4 novembre 1964. On a récolté 82.500 carpillons C_1, d'un poids total de 9.075 kg soit 15.000 carpillons ou 1.650 kg/ha.

Poids moyen : 110 g
Coefficient de nourriture : 2,18
Perte totale : 45 pour cent

Cette feuille aussi était en bonne santé, bien engraissée et exceptionnelle pour la reproduction.

En 1965 on s'attend à de meilleurs résultats encore, cependant pour les connaître il faut attendre que tout le poisson soit récolté et que tout le matériel soit rangé et élaboré.

5 CONCLUSION

Tous ces essais ont démontré qu'on peut obtenir dans les conditions yougoslaves, une production élevée de la feuille nécessaire pour une haute production du poisson à consommer sans avoir agrandi les superficies des étangs pour la production de la feuille aux dépens des superficies destinées à la production du poisson à consommer et sans nouveaux investissements, mais il faut soigner régulièrement les étangs destinés à la production de la feuille, tenir compte d'une alimentation correcte ainsi que d'un élevage correct de la feuille.

Les essais ont démontré aussi qu'on peut obtenir de bons résultats sans les divers concentrés et sans ajouter les vitamines, les antibiotiques ou les microéléments à la nourriture. L'essentiel est que la nourriture soit riche en protéines et tout le reste se trouve déjà dans la nourriture naturelle. La fumure régulière de l'étang à plusieurs reprises joue un grand rôle, parce que la production organique, c'est-à-dire la production de la nourriture naturelle devient ainsi constante, et la nourriture naturelle produite correspond, d'après sa structure et sa grandeur, à l'âge de la feuille.

Ces essais ont démontré également que pour une haute production de la feuille ce ne sont ni la méthode de frai (naturel ou artificiel), ni le système (complet ou incomplet de Dubisch) qui importent, mais la manière de traiter les alevins, leur nutrition et les soins que l'on doit leur donner.

De tous ces essais on peut conclure que la production moyenne de la feuille dans les étangs à carpes en Yougoslavie pourrait s'élever à 1.550 - 1.600 kg/ha environ ce qui correspondrait à la moyenne de la production du poisson à consommer.

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MONO-SEX CULTURE OF MALE TILAPIA NILOTICA LINNAEUS IN PONDS STOCKED AT THREE RATES

by

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Abstract

An experiment conducted to obtain information on mono-sex culture of male *T. nilotica* showed that production was not adversely affected by stocking up to 5,039 fish per ha. It was also shown that the fish did not grow at a constant daily rate during the experimental period.

ELEVAGE MONO-SEXUEL DE TILAPIA NILOTICA LINNEAUS MALES DANS DES EXPERIENCES MENEES EN ETANG AVEC TROIS TAUX D'EMPOISSONNEMENT DIFFERENTS

Résumé

Une expérience visant à obtenir des renseignements sur l'élevage mono-sexuel de *T. nilotica* mâle a révélé qu'une charge allant jusqu'à 5,039 poissons par hectare n'avait pas d'influence défavorable sur la production. On a également constaté au cours de l'expérience que le taux de croissance journalier des poissons n'était pas uniforme.

CULTIVO MONOSEXUAL DE MACHOS DE TILAPIA NILOTICA LINNEAUS EN ESTANQUES POBLADOS EN TRES PROPORCIONES

Extracto

Un experimento realizado para obtener información sobre el cultivo monosexual de macho *T. nilotica* mostró que la producción no se veía perjudicada en una proporción de repoblación de hasta 5.039 peces por hectárea. Igualmente se observó que el pescado no crecía durante el período experimental a un ritmo diario constante.

1 INTRODUCTION

Mono-sex culture using male Tilapia nilotica solves both the problems of undersirable reproduction and the slower growth rate of females that normally interfere with maximum production of usable-sized fish of this species. Unfortunately there has been little work in the United States on mono-sex culture of any species of fish. There is little information on stocking rates, growth rates, or production that can be obtained at different stocking rates.

This research was designed to obtain information on production by mono-sex culture of the males of T. nilotica using supplemental feeding, and to obtain information on the effects of three stocking densities on production.

2 EXPERIMENTAL PROCEDURE

The tilapia used in this experiment were approximately 1-year old. They were produced in brood ponds during the summer of 1959. The fish were removed from rearing ponds in the early fall of that year and maintained in warmed water inside a laboratory building during the winter.

When the fish were stocked in the experimental ponds April 29, 1960, they averaged 100 g each. Three ponds each 2.02 hectares in area were used in the experiment. The ponds were stocked at rates of 2,519; 3,804 and 5,039 fish per hectare, respectively.

Fish were fed the pelleted Auburn No. 2 fish feed (35 percent peanut meal, 35 percent soybean meal, 15 percent fish meal, 15 percent distillers'dry solubles). The fish were fed six days per week at a rate of 1.5 percent per day of the estimated weight of fish in the pond. Weight of fish in the pond was estimated by assuming that the fish would grow at a rate of 1.27 percent per day. By starting with the weight stocked, the estimated weight in each pond for a given day could be obtained by expanding the 1.27 percent daily growth rate to the desired number of days. The assumption of a constant daily growth rate implies an exponential growth curve for the period. The projected daily growth rate was estimated from data obtained in previous experiments with this species.

Samples of fish were taken by seining at intervals during the experimental period. The fish in the samples were counted, weighed and returned to the pond. All ponds were drained on 7 October 1960, or 163 days after stocking. The fish were removed on draining and counted and weighed.

3 RESULTS AND DISCUSSION

The results of the experiment are summarized in Table I. It is evident from the data that survival was about equal at the three rates of stocking; also that growth rates of the fish did not seem to be affected by rates of stocking. These results indicate that the stocking rate probably could have been increased without reducing rate of growth or without increasing the rate of mortality.

Although the fish at all stocking rates seemed to be growing at a maximum rate, production was only about 50 percent of the predicted level. This is of little consequence since it simply means that the estimated or predicted growth rate was too high; however, since the predicted growth rate was used to estimate the weight of fish in the pond on a given day for the purpose of determining the amount of feed to be given to the fish, the amount of feed was also too high resulting in conversion rates that are higher than conversion rates usually obtained with this species.

Table I

A summary of results obtained from an experiment on mono-sex culture with male Tilapia nilotica (where applicable all data are given on a per hectare basis)

Item	Pond		
	H-2	H-4	H-5
Number stocked	2,519	3,804	5,039
Percent survival	94	99	94
Weight stocked (Kg)	273	381	515
Weight recovered (Kg)	1,105	1,833	2,152
Net production (Kg)	832	1,452	1,637
Predicted net production[1] (Kg)	1,732	2,521	3,328
Amount of food fed (Kg)	1,788	2,817	3,783
Conversion	2.15	1.94	2.31

Table II

Observed and predicted average weights (g) of male T. nilotica in three experimental ponds

Pond	Number of days after stocking		
	42	123	130
H-2	318 (186)[2]	399 (513)	426 (630)
H-4	363 (177)	440 (494)	[3]
H-5	354 (177)	435 (494)	435 (603)

---

[1] Production predicted on basis of estimated daily growth rate of 1.27 percent and assuming 95 percent survival

[2] Predicted average weight

[3] No sample taken

Data presented in Table II indicate that the assumption of an exponential growth rate for even a portion of the experimental period was in error. The table includes observed average weights for fish in each pond determined from seine samples. Also included are estimated average weights if the fish had grown at the predicted rate of 1.27 percent per day. The data indicate that the predicted average weight was much lower than the observed weight after 42 days, a little higher after 123 days and much higher after 130 days. Rather than an exponential rate of growth, the observed average weights indicate a situation in which the daily growth rate decreased with time and/or size. Utilization of feed would have been more efficient if the amount to be fed had been determined by periodic estimates of average weights from seined samples.

4 CONCLUSIONS

The experiment on the mono-sex culture of male T. nilotica indicated three conclusions: (i) stocking rates of up to 5,039 fish per hectare did not seem to affect either the rate of mortality or rate of growth of this species; (ii) the assumption of a constant daily growth rate was incorrect. Rather the daily growth apparently decreased as the size of the fish increased or with time; (iii) determination of the amount of food to be fed daily by assuming a constant rate of growth resulted in feeding too much for efficient conversion. Assessment of food requirements should probably be based on seined samples.

****

STUDIES ON THE PHYSIOLOGY OF YOUNG TILAPIA

by

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Abstract

The paper summarizes the results of studies on temperature tolerance of young *Tilapia nilotica*, its resistance to the weedicides Weedazol and Aquathol Plus, the normal oxygen consumption at 25°C and the minimum oxygen requirements of young *Tilapia nilotica* and *Tilapia galilaea* and the reaction of *T. nilotica* to different electrical impulses.

The results of preliminary experiments in holding *T. nilotica* in a factory pond are also discussed.

V/E-6

ETUDES SUR LA PHYSIOLOGIE DES JEUNES TILAPIA

Résumé

Dans cette communication se trouvent résumés les résultats d'expériences sur la tolérance thermique des jeunes *Tilapia nilotica*, leur résistance aux herbicides Weedazol et Aquathol plus, leur consommation normale d'oxygène à 25°C, les besoins minimum en oxygène des jeunes *T. nilotica* et *T. galilaea* et enfin la réaction de *T. nilotica* à différentes impulsions électriques.

Les résultats d'une première expérience d'élevage de *T. nilotica* dans un bassin d'usine sont également examinés.

ESTUDIOS SOBRE LA FISIOLOGIA DE LA TILAPIA JOVEN

Extracto

En este trabajo se resumen los resultados de los estudios sobre tolerancia a la temperatura de *Tilapia nilotica* joven, su resistencia a los herbicidas Weedazol y aquathol y además el consumo normal de oxígeno a 25°C y las necesidades mínimas de oxígeno de los indivíduos jóvenes de *T. nilotica* y *T. galilaea*, y la reacción de *T. nilotica* a diferentes impulsos eléctricos.

Se examinan también los resultados de los experimentos preliminares de mantenimiento de *T. nilotica* en un estanque piscifactoría.

1 INTRODUCTION

Tilapia galilaea and *T. nilotica*, two of the largest species of tilapia (40 to 50 cm length), are widely distributed in Asia Minor and East and Central Africa. They are important economic fish in East Africa and the Congo.

In recent years tilapia have been studied in Germany by Peters (1963), and Dambach (1963), so when a commercial pond-fish interest suggested keeping tilapia in factory cooling ponds, where the water is between 20°-40°C summer and winter, physiological experiments were planned for tilapia, comparable to those made on rainbow trout (*Salmo gairdneri*), the most frequently-raised pond fish. Small *Tilapia nilotica* and *T. galilaea* were used, some raised in Germany (at the Zoological Institute of the University of Tübingen) and some imported from Israel by air. They were kept in aquaria at a constant temperature of 29°C and were fed mainly on a special food for trout fry ("Fukosalm") together with *Tubifex* worms, and fresh and crushed plants (*Elodea canadensis*, *Callitriche polymorpha* and lettuce leaves).

2 TEMPERATURE TOLERANCE OF *TILAPIA NILOTICA*

Trials were first made to find the temperature limits, both upper and lower, within which the fish stay alive. Previous work on rainbow trout suggested the respiratory rate (number of breaths a minute) to be a useful criterion of the state of the fish. Schmeing-Engerding (1953) established that in rainbow trout the preferred temperatures lay within the range of those within which the fish were able to compensate without difficulty for the lower oxygen content of the water by raising their rate of breathing. Tests on carp, groundlings, minnows, perch and trout confirmed that the respiratory rate provides the most adequate test of the fish's reaction to temperature, and the clearest index of its normal or pathological state.

The experimental procedure used was as follows: 25 fish of each series were introduced into a five-litre Erlemeyer flask standing air-insulated on an electric heating plate. The rise in temperature was - after a number of control tests - regulated by an electric resistance switch and the temperature was controlled with a calibrated thermometer (Fig. 1a). The water was kept saturated with oxygen and well mixed. The respiratory rate was counted with a stop watch.

To determine the lower temperature limit the same test arrangement was built in an icebox in which the door was replaced by a glass window and the base carried electric wiring (Fig. 1b). In all these tests raising and lowering the temperature from degree to degree took 10.4 minutes. The whole scale was run through in five hours 43 minutes, long enough to guarantee a sufficient functional adaptation of the fish to the temperature of the external surroundings (Denzer, 1948).

The respiratory rates of *T. nilotica* at various temperatures were as follows:

Temperature °C	Breathing frequency per minute	Temperature °C	Breathing frequency per minute	Temperature °C	Breathing frequency per minute
10	-	21	104	32	252
11	58	22	114	33	260
12	62	23	128	34	262
13	68	24	148	35	278
14	62	25	168	36	269
15	68	26	195	37	264
16	76	27	222	38	262
17	98	28	225	39	265
18	92	29	240	40	239
19	102	30	233	41	232
20	98	31	258	42	214
				43	-

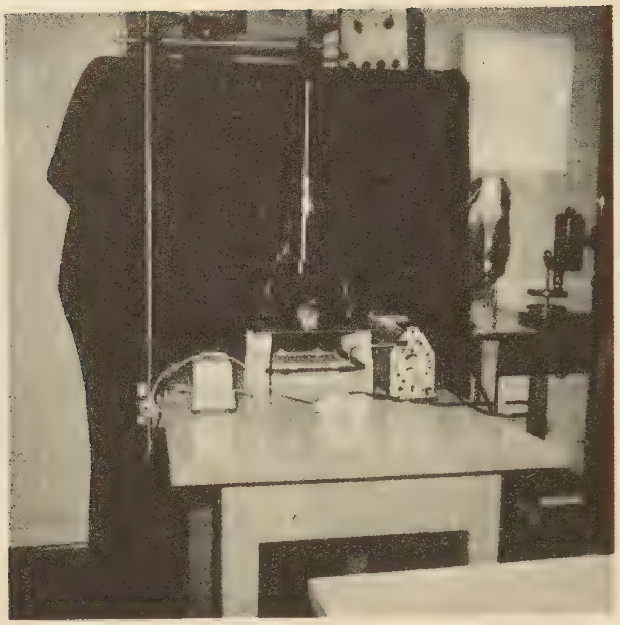

Fig. 1a The apparatus used for the study of high temperature tolerance of Tilapia nilotica

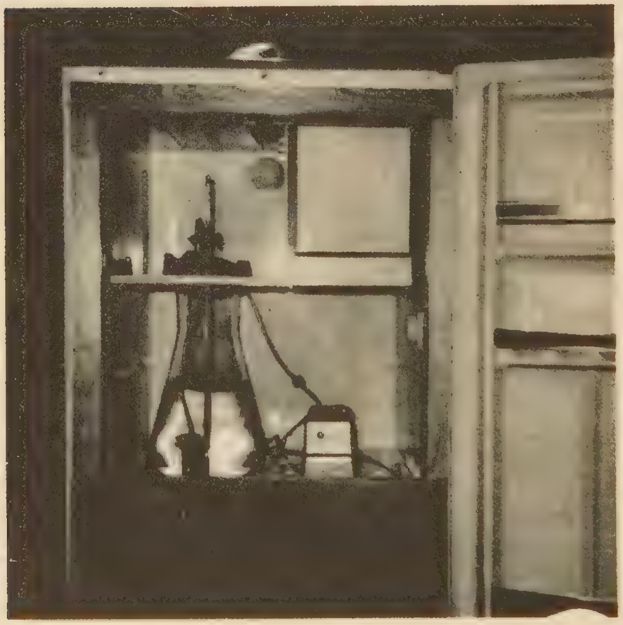

Fig. 1b The apparatus used for the udy of low temperature toleranc of Tilapia nilotica

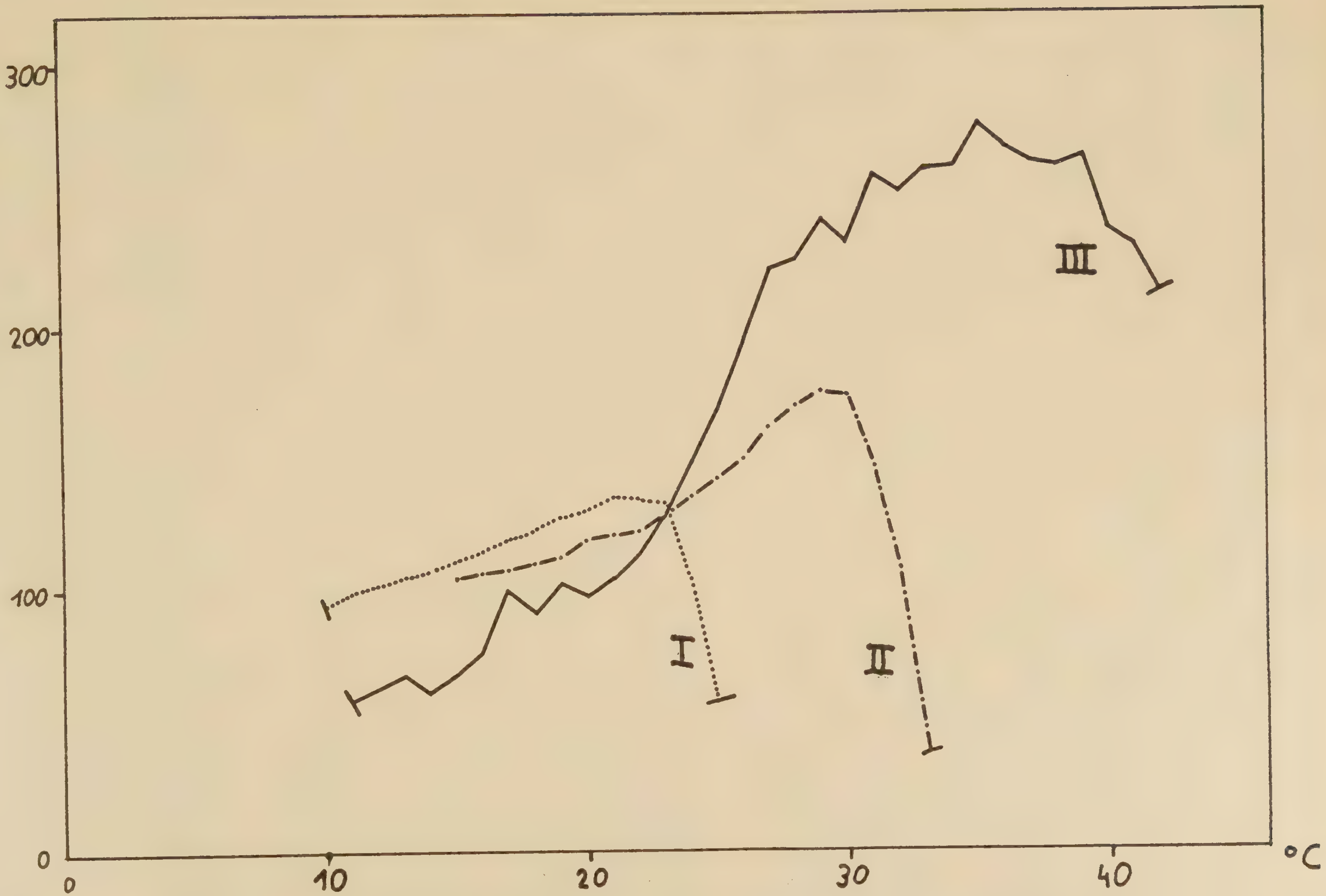

Fig. 2 The respiratory rates (per minute) of T. nilotica at various temperatures (°C)

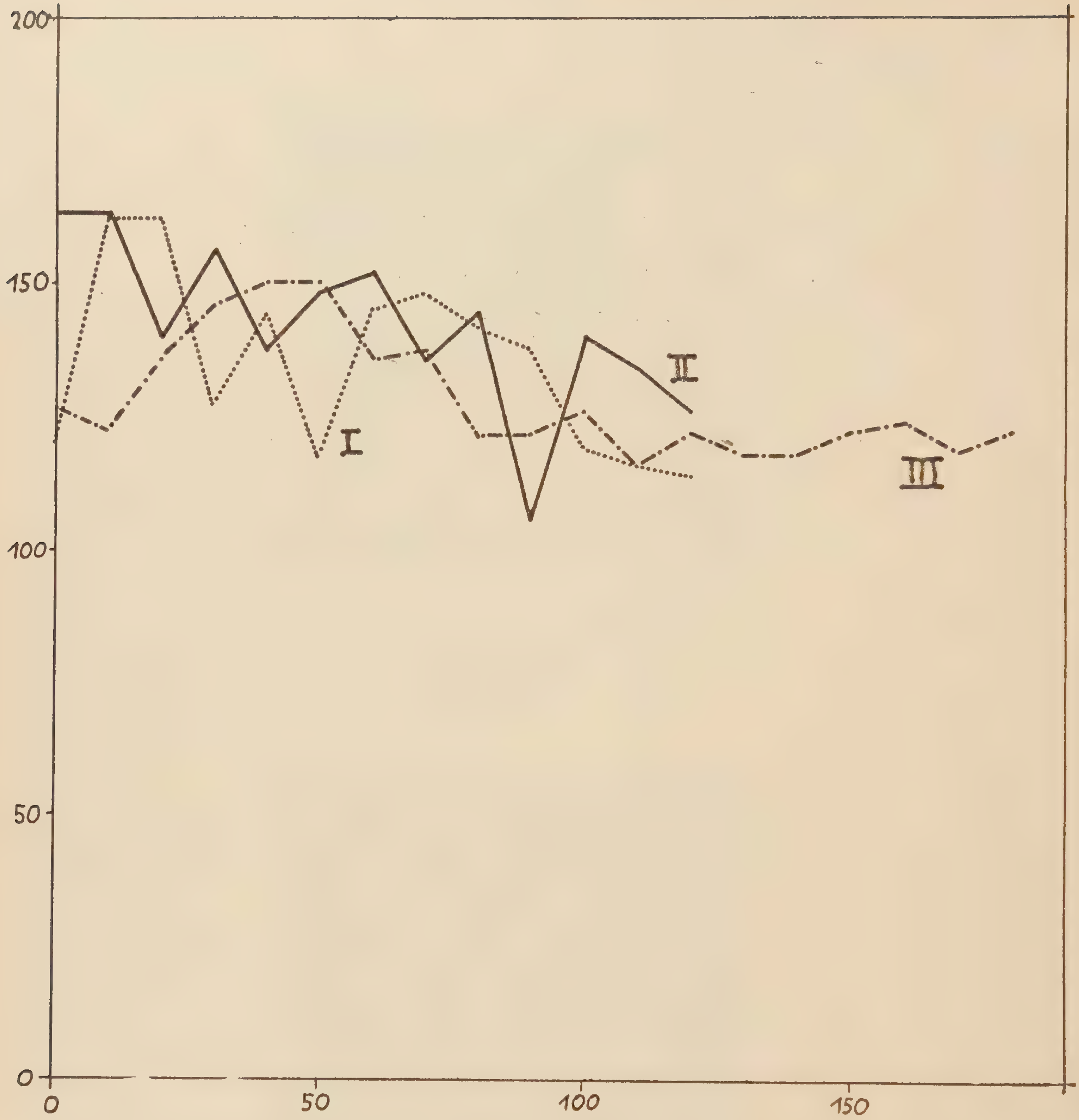

Fig. 3 Respiratory rates at reduced pressures in T. nilotica. (The ordinate represents respiration per minute and the abciss, time in minutes)

I 353.6 mm mercury pressure
II 266.6 mm mercury pressure
III 247.8 mm mercury pressure

T. nilotica died below 11°C and above 42° as is shown in Fig.2, in which the variation in respiratory rate with water temperature in T. nilotica is compared with that in rainbow trout and Idus idus.

T. nilotica compensated for the lower oxygen with rising temperature by increased respiratory rate, and it is noteworthy that the highest temperature they reached with continuously rising compensation is also the spawning temperature of these fish. Above this temperature the compensation was imperfect. It has been shown by previous workers that water reaches an oxygen saturation of 7.04 mg/l at 35°C and of 6.59 mg/l at 40°C. The actual values measured here were 6.91 mg/l at 35°C and 6.39 mg/l at 40°C because the atmospheric pressure during the experiments was always below 760° at sea level and the laboratory lies 375 m above sea level.

3 OXYGEN DEMAND AT REDUCED PRESSURES ("ALTITUDE TESTS") IN TILAPIA NILOTICA

During the temperature tests the available oxygen was low because of the raised temperature. But the total metabolism also rises with rising temperature, even though the available oxygen continually falls. In order to compensate for this rise in metabolic rate accompanying reduction of oxygen when the temperature is raised, a second series of tests were made in which the oxygen was reduced by lowering the pressure in a low pressure chamber. In this case the fish were quickly - within five minutes - brought to a predetermined pressure level and their respiratory rate then measured at the decreased pressure with its lower available oxygen. Since a certain pressure corresponds to a certain altitude, such tests are frequently applied to mammals as "altitude tests".

The apparatus used for the altitude tests consisted of a five-litre desiccator, with a side tube and cover both controlled by stopcocks, fitted with three litres of water (reaching to about 1 cm below the side tube). A short rubber tube and stone spreader was attached to the stopcock for inflowing air, provided with a Rossignol valve to regulate the fresh air supply caused by the low pressure. The side tube led to a Medvak pump with adjustable rotation velocity and a mercury barometer indicating the low pressure. The experimenter regulated the evacuation velocity in such a way that a continuously equal fresh air supply was guaranteed. The low pressure was callibrated against a balloon control barometer. The water temperature was kept at 25°C, a temperature within the range of complete compensation. At intervals of every ten minutes the respiratory rate was measured. The test lasted 120 minutes. The fish were exposed to these altitude tests in four groups. Group 1 remained for 120 minutes at 353.6 mm mercury (Hg) pressure (equivalent to 6,000 in altitude); group 2 for 120 minutes at 266.6 mm Hg (equivalent to 8,000 m); group 3 for 180 minutes at 247.8 mm Hg (equivalent to 8,500 m); and group 4 to 237 mm Hg (equivalent to 8,750 m).

In groups 1 and 2 the respiratory rate fell, with great fluctuations to 120, and to a similar value in group 3 after a short rise. In group 4 all fish died within the first ten minutes (Fig.3). The group 3 fish stayed alive for 180 minutes with available oxygen of only 2.7 mg/l and at 147.8 mm Hg pressure at a little less than one-third atmosphere, 2.7 mg/l.

This amount of available oxygen appears astonishingly small compared with the 6.7 mg/l available oxygen at 42°C when the fish died during the test. However, when it is taken into account that the amount of oxygen needed for metabolism at 42°C is much greater than at 25°C, it becomes clear that the difference in response to quantity of available oxygen is conditioned by the raised oxygen demand due to increased temperature.

4 OXYGEN CONSUMPTION IN TILAPIA GALILAEA AND T. NILOTICA

To find out the amount of oxygen consumed by Tilapia galilaea and Tilapia nilotica at 25°C, two groups of fish, Tilapia galilaea (of average weight 10.2 g) and Tilapia nilotica (of average weight 2 g) were tested in a flow-through experiment. This test has been described by Schlieper (1940) and has often been used by his pupils for the determination of oxygen consumption of fish. The test arrangement consists of a vessel filled with well-aerated water of test temperature, a fish-chamber consisting of a glass tube with in- and outlets, a Winkler-flask for the determination of oxygen, a funnel and a measuring jar for measuring the flow-through velocity of the test arrangement. The flow velocity is adjusted with the help of a squeezing cock fixed between vessel and fish-chamber. The fish chamber and the vessel are connected by a rubber hose, as is also the end of the fish-chamber with the Winkler-flask or the funnel. The principle of this test is to determine the oxygen content of a special amount of water before and after the flow-through. The oxygen consumed = oxygen content of the flowing water, in cc/l, less the oxygen content of the out-flowing water, in cc/l, multiplied by the amount of water flowing through in litres per hour. To get comparable values the oxygen consumption is calculated on the basis of 100 g of live weight of the fish. In order to keep the temperature as constant as possible, the room was brought to approximately uniform temperature. Any disturbance of the fish was avoided as far as possible to prevent unnecessary movement.

The results showed a comparatively small oxygen demand per 100 g of live weight. For *Tilapia galilaea* it amounted to 26.9 cc, corresponding to 38.42 mg, and for *Tilapia nilotica* 14.8 cc corresponding to 21.4 mg per hour. These values are considerably lower than those for European fishes at a corresponding optimum temperature. Trout, for example, at a size comparable with *Tilapia nilotica* need 55.4 cc per hour per 100 g body weight, and at comparable size with *Tilapia galilaea* 34.0 cc per hour per 100 g live weight. Results of former studies on young trout have shown that the oxygen consumption depends to some extent upon the absolute size. Thus small fish need on an average more oxygen than larger ones. Trout of 10 g weight require 34.0 cc of oxygen for every 100 g weight, trout of 20 g weight 23.3 cc, trout of 30 g 11.1 cc, and trout of 40 g 5.3 cc. If we compare these data with the extraordinarily low values for small *Tilapia nilotica* the small oxygen demand of these fish becomes apparent. Even the value for *Tilapia galilaea* remains at 26.9 cc, essentially below the value for trout.

5 THE EFFECT OF WEEDICIDES ON *TILAPIA NILOTICA*

The control of undesired water plants is in tropical and subtropical ponds just as necessary as in many ponds of our temperate zone. In tropical zones control is even more difficult as the lack of fresh water flow often means that it is not possible to drain the pond and refill it anew after the plants are removed. For eradicating undesired flora in stock ponds the preparation Weedazol (of the firm CELA, Ingelheim) a 3-amino-1,2,4 - triazole with the molecular formula $C_2H_4N_4$ - and the not-yet imported to the European market Aquathol resp. Aquathol Plus, an Endothale product (contact herbicide) of the Pensalt Chemicals Corporation at Tacoma, Washington, U.S.A., have proved successful. Both have a very strong effect, and destroy amongst other weeds, *Eichhornia* and *Potamogeton* species as well as *Equisetum*, *Phragmites*, *Phalana*, *Typha* and *Sparganium*. The maximal dose to be applied for controlling plants is 40 ppm of Weedazol and 4 ppm of Aquathol Plus. On account of its great importance in fish culture the "Landesanstalt für Fischerei" has tested the effect of such doses on *Tilapia nilotica*. Former tests had shown the tolerance limit for rainbow trout to be for Weedazol 1,000 ppm and for Aquathol Plus 1,100 ppm. On tests with *Tilapia nilotica* the fish were kept for 24 hours in a well-aerated glass bowl at 26°C. During the first two hours the breathing frequency was measured every 15 minutes, then for six hours once every hour, and again after 24 hours.

We have found after numerous toxicity tests that fish with a low oxygen demand generally seem to be less sensitive to toxins than fish with a high oxygen demand. It could be taken for granted that *Tilapia nilotica* would stand higher concentrations of Weedazol and Aquathol Plus than European fishes, and this proved to be so. *Tilapia nilotica* showed a marked change of breathing frequency only at 2,100 ppm Weedazol and with Aquathol Plus at 2,900 ppm. This proves that Weedazol and Aquathol Plus may be applied in ponds stocked with *Tilapia nilotica* without harm to the fish.

6 THE USE OF ELECTRIC FISHING DEVICES TO CATCH TILAPIA NILOTICA

Where ponds cannot be drained, fishing with net or electric apparatus is necessary. Of these two ways the electric fishing does less harm to the fish. In ponds with high temperatures, however, if not very poor in minerals, the conductivity is very high, so that fishing with a scare chain, a method of fishing to be preferred to all other methods, might cause difficulties if the power of the catching apparatus is not very great. In this case a pulse sender with a continuous pulse regulation is advised as additional apparatus for middle and small aggregates. Since, however, it is known that at high temperatures very short pulse pauses must be chosen, as the swimming movements are very quick and the reaction of each kind of fish is specific generally and also upon impulses, the behaviour of a number of *Tilapia nilotica* was tested within an electric field, in order to find out which direct current voltage (body voltage) is required for *Tilapia nilotica* and which pulse and pause periods guarantee a sure anodic reaction.

For this purpose the fish were put into a glass aquarium with whole-side electrodes to which the current was conducted through a commutator to allow an exchange of the positive and negative pole in order to avoid spot training of the fish. For direct current, the effect of which was tested first, impulses were taken from an alternating current network and electronically rectified and smoothed in a pantostate and then conducted to the commutator. Parallel to the electrodes a sensitive direct current meter (Multavi) was inserted. The voltage could be calculated from the length of the aquarium, the voltage at the electrodes in case of marked anodic reaction, and the length of the fish.

The testing of 25 fish showed a body voltage between 3.16 and 4.08 (at a temperature of 25°C), with an average of 3.66 volts. Thereafter the same fish were brought into a wooden aquarium of 200 cm length and 50 cm breadth and exposed to different impulses. The impulse current was formed with the help of a home-made electronically working impulse generator, taken from an alternating current net over a rectifier with parallel connected capaciters of high capacity. The temperature of the bath was again 25°C, and the commutator allowed the exchange of the positive and negative electrodes.

These experiments in which the effect of the impulse current was tested showed 100 percent anodic reaction and pulse frequency of 80 at an impulse duration of 3 ms and a pause duration of 9.5 ms. A non-specific reaction did not occur. These are very favourable values for the catching of fish at high temperatures. For comparison, carps require an impulse duration of 5 ms. This two-fifth shortened reaction time means an essential protection against a threatened voltage drop, a very high conductivity, and high temperatures. Thereby it is proved that anodic fishing with the indicated form of impulse is possible.

A scaring effect desired for the catching chain occurred at low frequency impulses; thus at 20 frequencies at an impulse length of 25 ms and equally long pause. This is easily understood, for at high temperatures the fish move fast and react quickly so that during long pauses the stimulant soon dies out and flight begins. Here the reaction of the fish almost reversed cathodically, as 60 percent reacted cathodically, 15 percent anodically and the rest non-specifically.

These results prove without doubt that *Tilapia nilotica* can well be scared and caught electrically, provided that fully adjustable impulse instruments are used, and the fisher knows exactly which impulse is required for the special purpose.

7 A FACTORY COOLING POND TRIAL WITH TILAPIA NILOTICA

An attempt to store *Tilapia* species in factory cooling ponds was made by the "Landesanstalt für Fischerei". Suitable fish, 436 *Tilapia nilotica* of 2 to 3 cm length were however only received in August of this year (1965). The pond intended for this purpose is wholly made of concrete of 400 sq/m size, with an average depth of 1.20 m and an average temerature of 28°C during the whole year. The temperature may rise in mid-summer to 40°C and in a cold winter fall to 22°C. Within this range of temperature there is no risk to life for the fish. There is sufficient oxygen. The water is nearly saturated with oxygen since a part of the cooling water rises over a frame of perforated pipes standing in the middle of the pond and from there drops into the pond. The other part of the in-flow water passes over a settling basin and an oil-separator into the pond. On the opposite side, the water is sucked back into the cycle through a bottom outlet provided with a sieve.

On 11 August 1965, 436 Tilapia nilotica were stocked. They had a total weight of 4,095 g and were fed every day 100 g of Fukosalm - food for young fishes, approximately 2.5 percent of their total weight. Since stocking, only one dead fish has been observed till the end of September. The fish stay in shoals and pass through the whole pond and feeding on, amongst others, green algae which they find especially near the tower. At the end of this winter the pond is to be fished electrically, in order to find out how many fish have survived and how much they have grown.

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A MECHANIZED HAUL SEINE FOR USE IN FARM PONDS

by

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Abstract

Research and development activities by the U.S. Bureau of Commercial Fisheries, aimed at improving methods and equipment for harvesting commercial food fish produced in flooded rice fields and various other farm ponds in the South Central States, have resulted in the design and fabrication of a variable-length haul seine along with mechanized means for handling the net and its large catches of fish for use in ponds ranging from 1.6 ha (4 acres) to 20.2 ha (50 acres) in size. Buffalofish (Ictiobus sp.) and catfish (Ictalurus sp.) were caught in amounts up to 15,138.9 kg (33,375 lb) per set during experimental and demonstration trials with a net up to 627.8 m (2,060 ft) in length. Advantages of harvesting fish from large ponds without draining include conserving valuable water, having fish stocks readily available for short-notice market requirements, maintaining excellent quality of fish - even for live transfer, and reducing the cost of operations. Mechanical and manual methods and equipment are described, illustrated and compared.

V/E-7

UNE SENNE TRAINANTE MECANISEE CONCUE POUR LES ETANGS DE PISCICULTURE

Résumé

En vue d'améliorer les méthodes et l'équipement en usage pour la récolte commerciale des poissons élevés en rivières inondées et dans d'autres étangs dans les Etats du centre-sud, le U.S. Bureau of Commercial Fisheries a fait des travaux de recherche et de mise au point technique qui ont abouti à la fabrication d'une senne traînante de longueur variable, avec moyens mécaniques pour rentrer le filet et ses lourdes prises; cet engin peut être utilisé dans des étangs d'une superficie allant de 1,6 ha à 20,2 Ha. Au cours d'essais et de démonstrations, des prises de Buffalofish (*Ictiobus* sp.) et de Catfish (*Ictalurus* sp.) allant jusqu'à 15, 138,9 kg par pose ont été effectuées avec un filet d'une longueur maximum de 627,8 m. La possibilité de récolter le poisson dans de grands étangs, sans mise à sec, comporte de nombreux avantages: conservation d'une eau précieuse, stocks facilement disponibles pour satisfaire rapidement les demandes du marché, maintien d'une qualité excellente - permettant même le transport de poissons vivants - et diminution des frais d'exploitation. Cette communication donne une description comparée et illustrée des méthodes mécaniques et manuelles et du matériel employé.

RED DE CERCO MECANIZADA PARA SU EMPLEO EN ESTANQUES AGRICOLAS

Extracto

Las actividades de investigación y fomento realizadas por el Centro de Pesca Comercial de E.U.A., destinadas a mejorar los métodos y el equipo de recolección de los peces producidos en los arrozales inundados y en varios estanques de las granjas de los Estados Centrales del Sur, se ha traducido en el diseño y fabricación de una red de cerco de longitud variable, junto con medios mecanizados para manejar la red y sus grandes capturas de peces, para usarla en estanques que miden desde 1,6 hectáreas (4 acres) hasta 20,2 hectáreas (50 acres). Se capturaron *Ictiobus* sp. y bagres (*Ictalurus* sp.) en cantidades de hasta 15.138,9 kg (33.375 libras) por lance durante pruebas experimentales y de demostración con una red de hasta 627,8 m (2.060 pies) de longitud. Las ventajas de recolectar peces de grandes estanques sin drenarlos incluyen el poder conservar aguas valiosas, disponer de poblaciones en cualquier momento para atender a las necesidades del mercado, conservar peces de excelente calidad incluso para transportarlos en vivo, y reducir los gastos de las operaciones. Se describen, ilustran y comparan métodos y equipo mecánicos y manuales.

1 INTRODUCTION

The United States Bureau of Commercial Fisheries is engaged in research and development activities aimed at the improvement of commercial fisheries based on production from flooded rice fields and other types of farm ponds and reservoirs located in the lower Mississippi river bottom lands area of the South Central United States. These activities have been concerned with improvement of harvesting methods, processing and storage methods, consumer products, and market development and promotion.

Since its beginning in the early 1950s, the commercial farm pond fishery has relied solely on traditional methods for catching and handling fish (Figs.1 and 2). Because these laborious methods often resulted in production costs exceeding the value of the fish removed, the development of effective and efficient harvesting and handling methods is of extreme importance from an economic standpoint.

Typically, extensive preparations are required to ready ponds and fish for harvesting. Draining a pond and preparing for final harvesting operations from sumps or ditches require several days. In addition, valuable water supplies are wasted. Under these conditions, it is difficult to coordinate production with market demands and often operations must be limited to periods of the year when fish harvesting does not conflict with other farm activities.

Investigations of fishing methods and equipment which would be applicable to commercial farm pond fisheries led to the development of a mechanized haul seine adapted for use in ponds and reservoirs having relatively uniform bottom contours. The mechanical haul seine was chosen for initial study and development for several reasons: first, a major portion of farm ponds are relatively flat-bottomed with little or no plant growth to interfere with seine operations or could be put in suitable condition without difficulty; second, a properly designed net could be used in ponds ranging in size from 0.4 to 64.7 ha (1 to 160 ac) or larger, depending on dimensions of the pond. Third, the net could be used in a wide variety of water depths ranging from sump basins or ditches to ponds that are filled with 1.8 to 2.4 m (6 to 8 ft) of water. Fourth, fish, in any amount, would be available for shipment at not more than 24 hours' notice. Fifth, manpower requirements would be reduced— two men can set and haul the net and three men can load the fish. Sixth, fish removed from undrained ponds would be in much better condition in that they will be alive, unmuddied, and handled less. Seventh, the net would be suitable for harvesting buffalofish or catfish – the two species most commonly produced. And eighth, important water supplies would be conserved.

2 EQUIPMENT

Major components of the mechanized haul seine system include five pieces of equipment: (i) seine, (ii) a mobile pontoon seine barge used for transporting the seine overland and setting it in ponds, (iii) seine puller, (iv) seine hauling lines, and (v) a fish conveyor for loading the catch after the seine is drawn ashore.

2.1 Seine

The seine consisting of two wings and a bag is constructed of synthetically treated nylon material, with a maximum overall length of 627.8 m (2.060 ft) and a depth of 3.1 m (10 ft). (See Fig. 3 and Table I for construction details and specifications).

2.1.1 Wings - Each of the wings is made up of six sections of various lengths and mesh sizes to facilitate rigging the seine to fish ponds of varying sizes. Mesh sizes vary from 10.1 cm (4 in) at the wing end to 3.8 cm (1.5 in) at the bag end (Fig.3, Table I). Large mesh sizes are used in the leading wing sections to reduce drag resistance during hauling. The ends of each section are provided with galvanized thimbles on the top and bottom lines to allow the sections to be joined together by either shackles or cordage material. Perpendicular breast lines at the ends of adjoining sections are laced together. Bridles and spreader bars attached at the leading edge of each wing serve to keep the seine wings open vertically and are also used for attaching the hauling line (Fig.3). Jute rope is attached to the bottom line of the wings (and bag) to weight down the bottom line and to prevent the seine from digging into bottom mud during hauling.

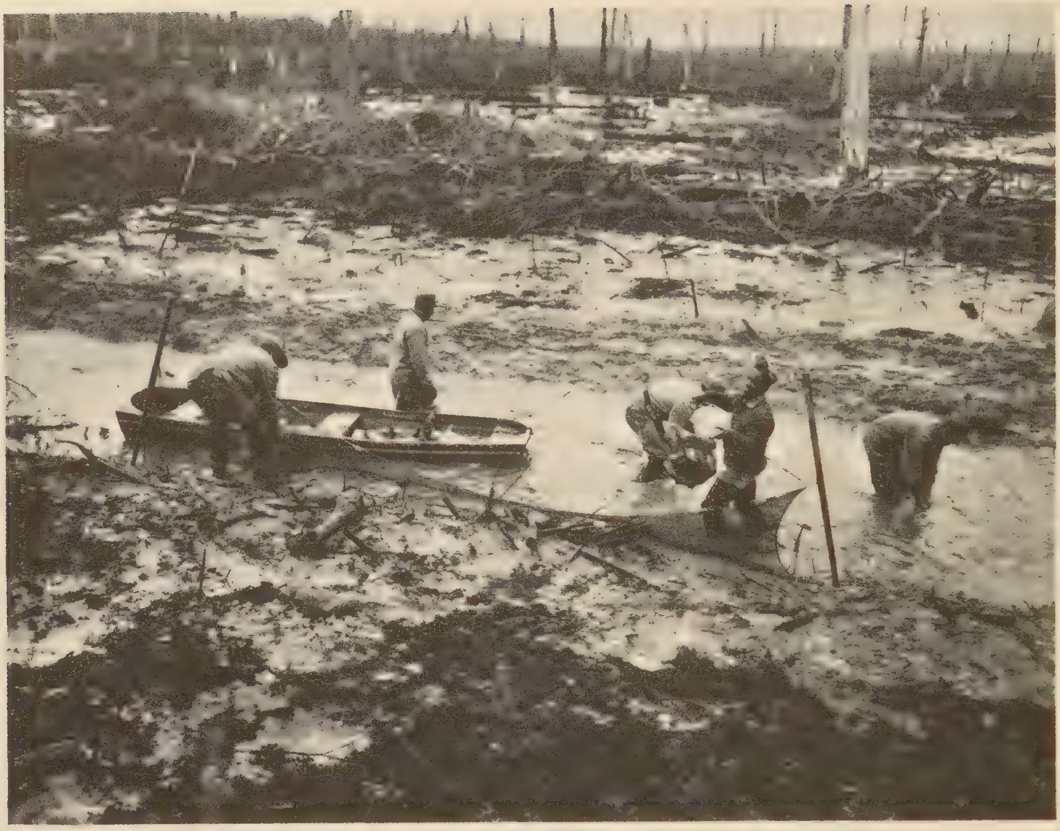

Fig. 1 Hand-dipping buffalofish from bar ditch or a drained woodlot reservoir. After the "John-boat" is filled with fish, about 227 kg, it is pushed through the debris-filled bar ditch approximately 1.2 km to a loading point.

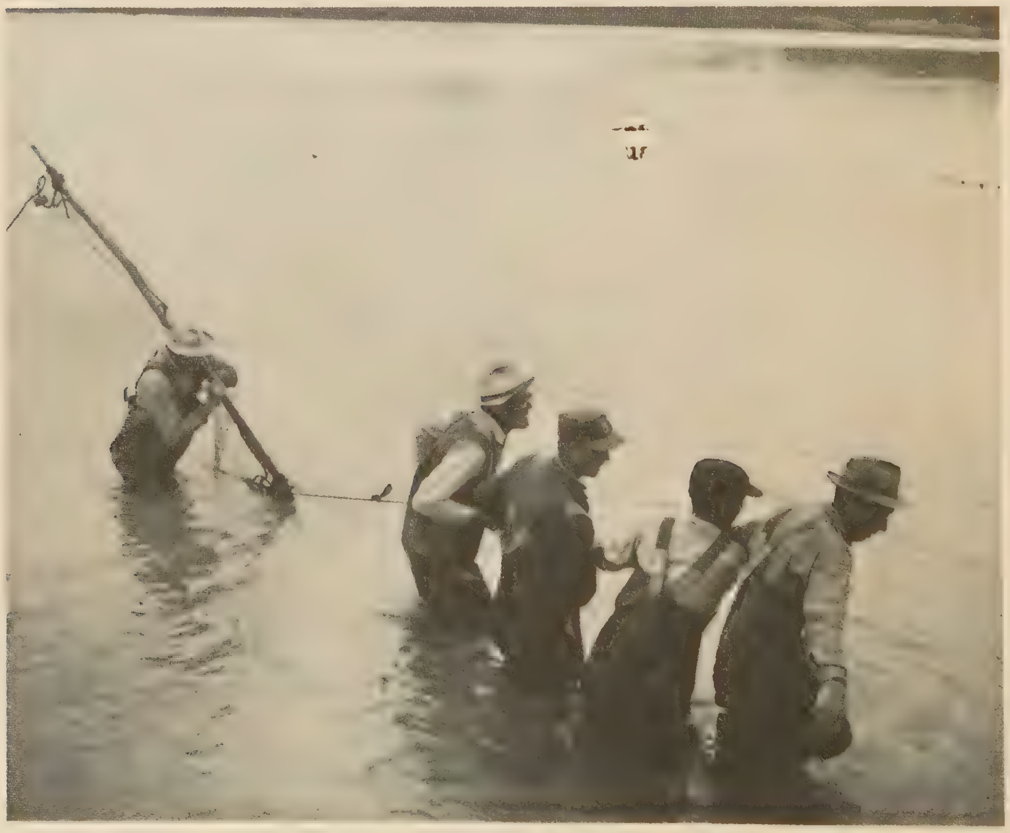

Fig. 2 Part of a seven-man crew in process of seining brood catfish from main pond for planting in holding ponds. The operation took seven hours to complete. A similar operation in the same pond could be accomplished in 1.5 hours by two men employing the mechanized haul seine.

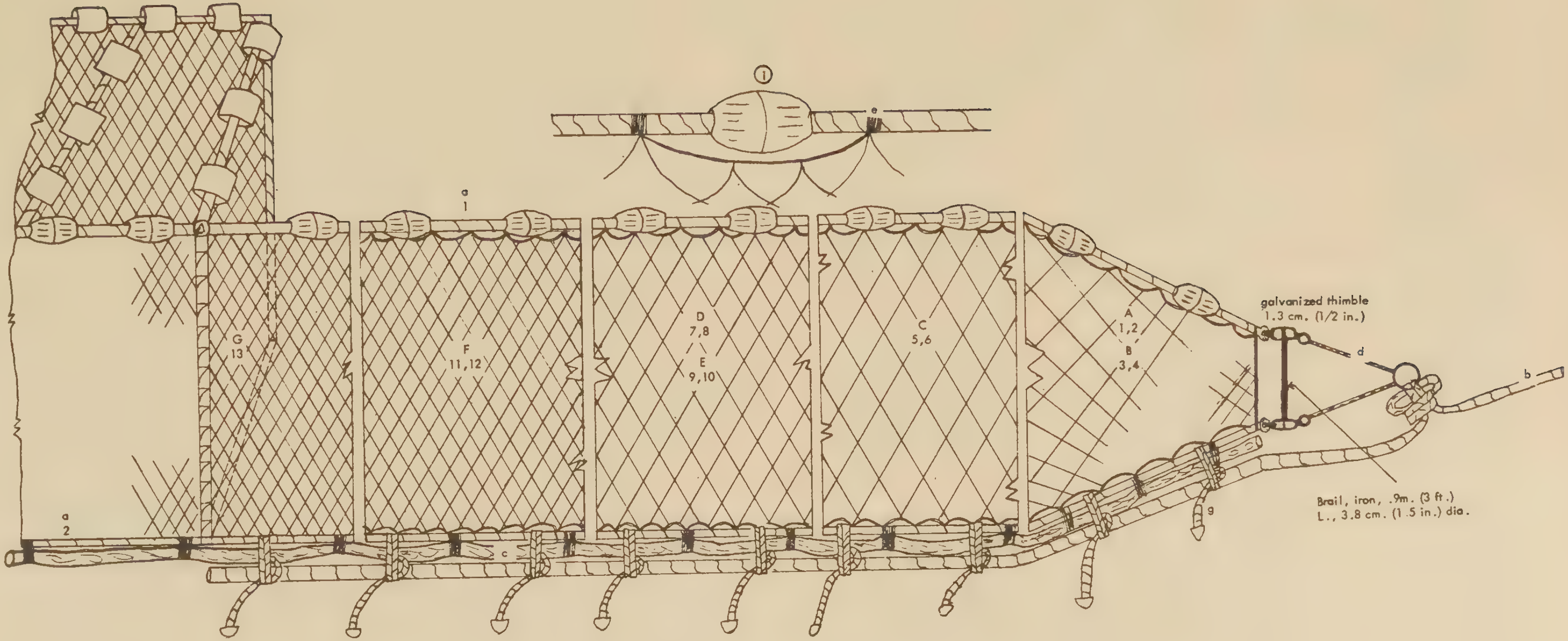
①
e
a
1
G
13
F
11,12
D
7,8
E
9,10
C
5,6
A
1,2
B
3,4
galvanized thimble
1.3 cm. (1/2 in.)
d
b
Brail, iron, .9m. (3 ft.)
L., 3.8 cm. (1.5 in.) dia.
g
c
a
2

Fig. 3 Construction details of farm pond haul seine

Table I

DATA SHEET

FAO NO.

NAME OF GEAR: Seine

TYPE: Haul

COUNTRY: United States

LOCALITY: South Central

REFERENCE:

Main species caught: Buffalofish and catfish

Fishing conditions:

Vessels:

L.O.A.

Gross Tonnage:

Horse Power:

Crew:

WEBBING	$A_{1,2}$	$B_{3,4}$	$C_{5,6}$	$D_{7,8}$	$E_{9,10}$	$F_{11,12}$	G_{13}
Material	nylon	→	→	→	→	→	→
Type of knot	sheet bend	→	→	→	→	→	→
Preservation	T	→	→	→	→	→	→
Color							
Twine size	865	→	→	921	→	→	→
Breaking kg. Strength lb.	43.5 96.0	→ →	→ →	51.7 114.0	→ →	→ →	→ →
Stretched mm. Measure in.	101.6 4.0	→ →	76.2 3.0	50.8 2.0	→ →	38.1 1.5	→ →
Upper Edge	900	→	600	1757	→	1280	1140
Lower Edge	1000	→	600	1757	→	1280	1140
Depth	43	→	60	87	→	120	→
Baiting Rate							
Take Up							
Selvedge	double	→	→	→	→	→	→
Hanging	.67	→	→	→	→	→	→

LINES, ROPES	a^1	a^2	b	c	d	e	f	g
Material	nylon	→	man.	jute.	swr	nylon	→	man.
Preservation	T	→				T	→	→
Circumference in.	1.5	1.5	2.3	6.2	1.1			1.5
Diameter mm.	12.0	12.0	19.0	50.0	9.3			12.0
Breaking kg. Strength lb.	3628 8000	→ →	2449 4000	 12,400	5449 →	54.8 121	362.8 800	1179 2600
Twist			3Z					3Z
Lay			M					M
Length m.	627.8	→	1463	627.8	0.9			1.0
Length ft.	2060	→	4800	2060	0.3			3.3

FLOATS, SINKERS	Floats
	(1)
Number	958
Material	Plastic
Shape	Oval
Diameter mm. in.	63.0 2.5
Length mm. in.	76 3.0
Static kg. Buoyancy lb.	
Weight kg. In Air lb.	
Weight kg. Submerged lb.	

2.1.2 Bag Section - The bag section of the seine consists of a bag 2.6 m (8-½ ft) wide, 3.1 m (10 ft) deep, and 3.1 m (10 ft) long with wing extensions 7.6 m (25 ft) long and 3.1 m (10 ft) deep on each side of the bag (Fig.3, Table I).

2.2 Seine barge

The seine barge (Fig.4) is a pontoon type craft with 2.4 by 6.1 m (8 by 20 ft) plywood deck platform. The barge is equipped with a 10 h.p. outboard motor in a well at the stern end, a steering and throttle console on the right side, and an aluminum roller, 1.35 m (53-½ in) long, 7.6 cm (3 in) diameter core and 38.1 cm (15 in) diameter flanges, mounted on the deck platform near the stern to allow stacking and setting of the net over the outboard motor. Transportation of the barge overland is achieved by four retractable 38.1 cm (15 in) by 19 cm (7.50 in) by 4 ply automobile tyres mounted between the pontoons midway fore and aft. The wheels are raised and lowered by means of a screw and gear box. A trailer hitch mounted on the front of the barge allows hauling by truck or tractor.

2.3 Seine puller

The seine is hauled by a seine puller modified to mount on the supporting frame beneath a fish conveyor and powered by a 4 h.p. gasoline engine (Fig.5). In this manner two pieces of equipment are combined into a single compact unit, a net puller-fish conveyor. Main assembly components of the seine puller and method of attaching the hauling line are shown in Fig 6. Later, a seine puller, similar in design, was built on a trailer to provide a smaller, more mobile unit to be used when the conveyor was not needed (Fig.7). Another experimental seine puller, tested with unsatisfactory results, involved the use of a double drum winch employing steel cable rather than rope, as a hauling line (Fig. 8).

2.4 Fish conveyor

A portable grain conveyor powered by a 5 h.p. gasoline engine was modified for handling fish (Figs. 5 and 9).The unit features a hinged fish chute and lifting apron attached to the receiving end of the conveyor, for loading fish from the seine. Both chute and lifting apron fold back onto the conveyor during transit and are lowered into the water during operation. Slots between the inside walls of the fish chute and lifting apron serve as fair leads for the hauling lines. A sectional canvas belt is attached to the drag chain between the cross bars to prevent fish from being caught under the cross bars when the conveyor is operated. Components of the unit are shown in Fig. 6.

2.5 Catch-weighing equipment

Two square wire baskets of 3.8 cm (1-1/2 in) mesh expanded steel, 0.6 x 0.6 x 0.33 m (24 x 24 x 13 in) are attached to the upper exit end of the conveyor to receive the fish, weigh them, and empty them into a truck on the pond bank (Fig.10). A tripping mechanism allows one side of the bottom to drop 25.4 cm (10 in) and deliver the fish out one side. The weighing baskets, each equipped with an 0-72.5 kg (0-160 lb) spring scale, are mounted on a revolving bar so that one basket can be filled while the other is being weighed and emptied.

2.6 Hauling line

The hauling line is 1.9 cm (3/4 in) diameter medium lay manila line which is made up into two 722 m (2,400 ft) lengths. It is attached along the length of the seine by means of 101.6 cm (40 in) toggle ropes of 1.27 cm (1/2 in) diameter manila fixed to the seine bottom line at intervals of 7.6 m (25 ft). Each toggle rope is fitted with a 3.8 cm by 6.3 cm (1-1/2 in by 2-1/2 in) white tapered wooden float on the free end to facilitate sighting and retrieving the lines which are untied from the hauling lines during the hauling operation.

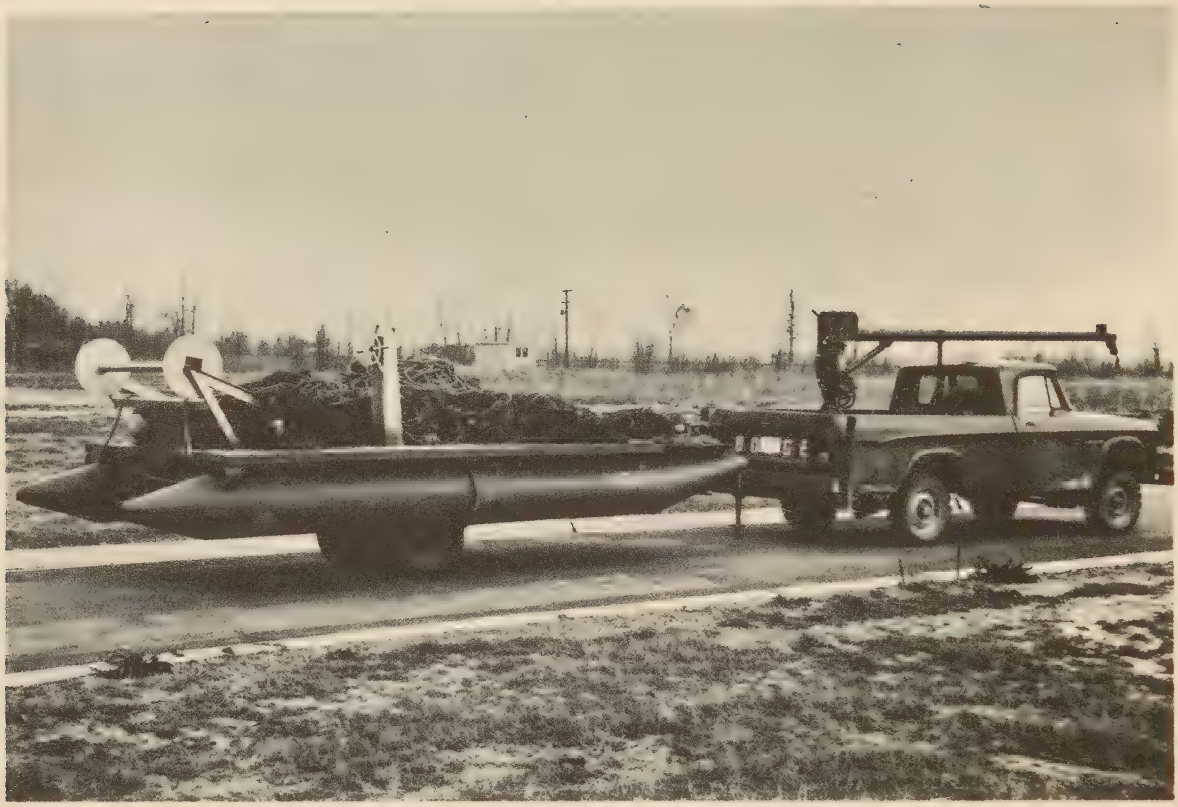

Fig. 4 Mobile pontoon barge used for hauling and setting farm pond haul seine

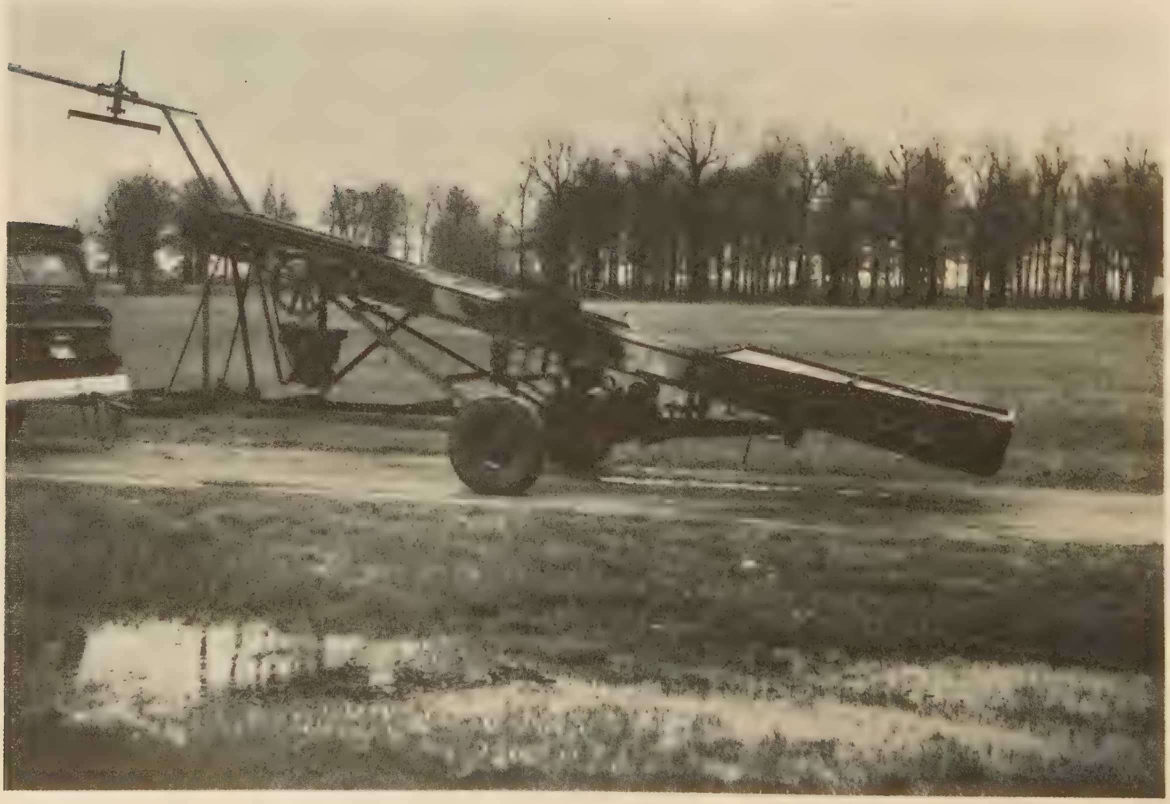

Fig. 5 Seine puller mounted on supporting frame beneath fish conveyor, combining seine puller and conveyor into single compact unit.

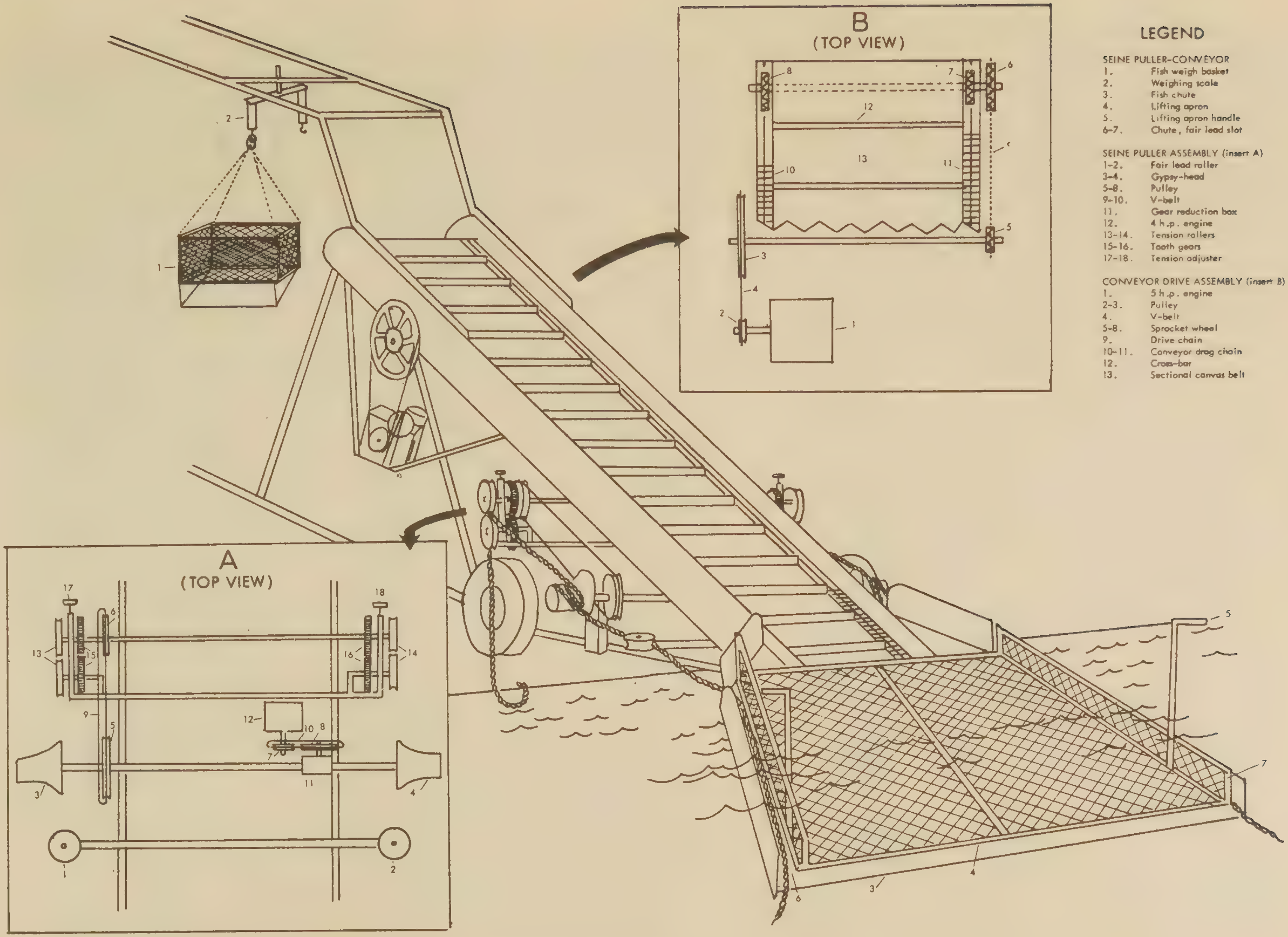
B
(TOP VIEW)
A
(TOP VIEW)
LEGEND
SEINE PULLER-CONVEYOR
1. Fish weigh basket
2. Weighing scale
3. Fish chute
4. Lifting apron
5. Lifting apron handle
6-7. Chute, fair lead slot
SEINE PULLER ASSEMBLY (insert A)
1-2. Fair lead roller
3-4. Gypsy-head
5-8. Pulley
9-10. V-belt
11. Gear reduction box
12. 4 h.p. engine
13-14. Tension rollers
15-16. Tooth gears
17-18. Tension adjuster
CONVEYOR DRIVE ASSEMBLY (insert B)
1. 5 h.p. engine
2-3. Pulley
4. V-belt
5-8. Sprocket wheel
9. Drive chain
10-11. Conveyor drag chain
12. Cross-bar
13. Sectional canvas belt

Fig. 6 Schematic drawing of combinatión seine puller-fish conveyor showing main components of system and method of attaching hauling lines

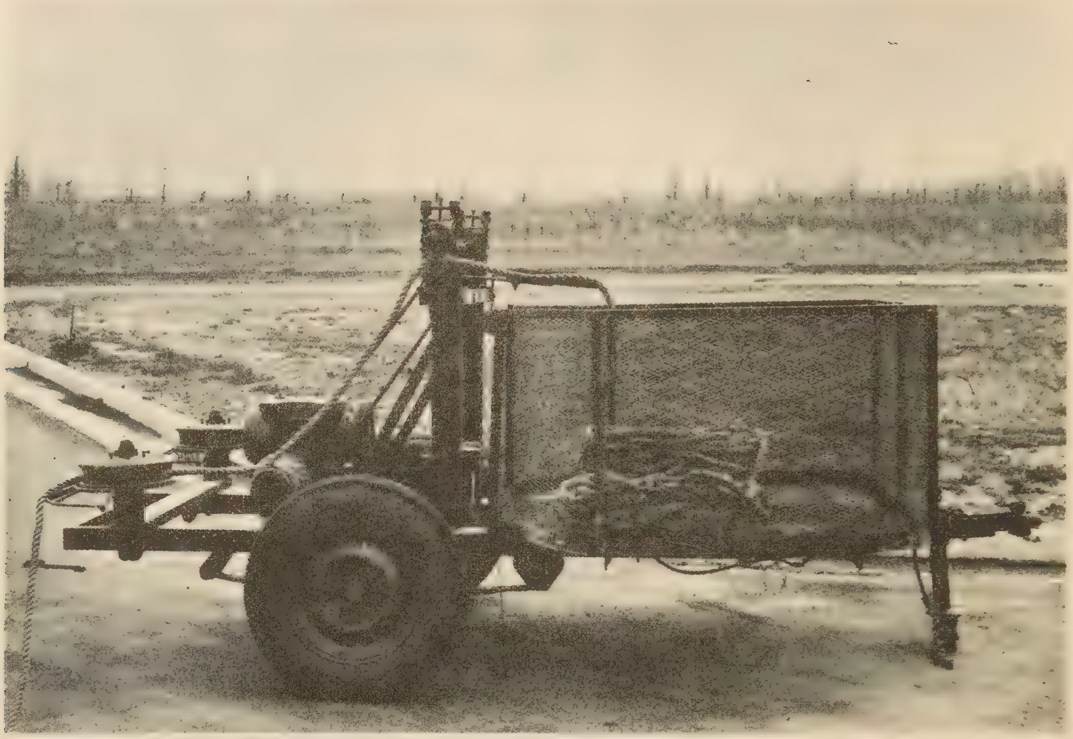

Fig. 7 Improved trailer-mounted seine puller. Equipment fills the requirements for an independent, compact unit.

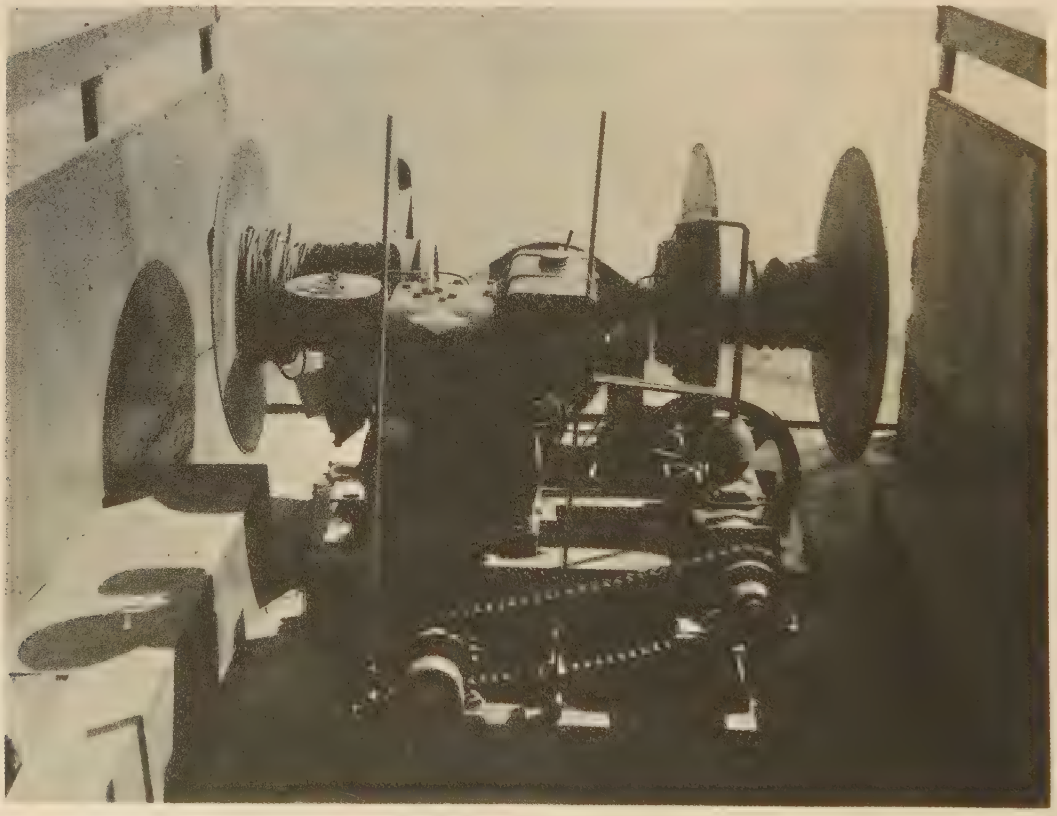

Fig. 8 Close up of aft end of Bureau-designed haul seine puller, employing cable for hauling lines. Earlier tests were conducted with puller mounted on trailer.

3 SEINING PROCEDURE

3.1 Preliminary set-up

Before setting the net, the seine puller or combination seine puller-conveyor is first positioned on the pond bank in the harvesting area. When operating the seine puller-conveyor unit, the receiving end of the conveyor is placed near the water's edge and the fish chute lowered into the water. Steel blocks, 20.3 cm (8 in) in diameter and provided with a rope slot in one block cheek, are then staked in position. One block is staked to the bank at each proximal corner. If the pond is of considerable length , a second block is used on each side of the pond. The net is staked on the barge beforehand with hauling lines attached to the bottom line of the seine. Stacking the seine is done in a manner to facilitate setting, i.e., left hauling line, left wing, bag section, right wing, and right hauling line in that order. Next the barge, with seine aboard, is launched and positioned directly in front of the puller (Fig.11). The leading end of the right hauling line is then fastened to the winch head, drawn past the fair-lead roller, and around the fair-lead all on the right side (when facing the pond) of the seine puller (see Fig. 6). The net is now ready to be set.

3.2 Setting the net

The haul lines and net are payed out as the barge travels counterclockwise around the perimeter of the pond. First, the right hauling line is payed out over the seine roller of the barge as it is propelled toward the block staked at the near right corner of the area to be seined. After the line is put through the corner block, the barge proceeds along the right side of the pond to the second block (if used) where the hauling line is threaded. The barge continues down the right side of the pond paying out the hauling line over the seine roller. Then, seine and line are set out simultaneously as the barge proceeds around the pond in a counterclockwise, semi-circle pattern (Fig. 12 A). The barge continues around the pond paying out the hauling line and passing it through the left side (if used) and corner blocks. Upon returning to shore, the barge is beached. Running the remaining hauling line through the fair-lead, by the fair-lead roller, and around the winch head all on the left side of the seine puller completes the setting operation and the net is ready for hauling (Fig. 12 B).

3.3 Hauling

After the seine puller engine is started, the hauling lines are wrapped three turns around the respective winch head, threaded between the tension rollers on the respective sides and hauling is commenced. The haul lines are retrieved at the rate of about 7.6 m (25 ft) per minute and are coiled on the ground by the tension rollers. When using the trailer-mounted puller, the lines are automatically coiled in a rope storage bin located beneath the tension rollers (see Fig.7). As hauling continues, the hauling lines are removed from the blocks at the sides and corners of the pond as the seine wing tips reach them (Fig.12 C). When the wing tips near the chute fair leads, two men standing just off shore in front of the conveyor chute, untie the toggle ropes from the hauling lines, and stack the seine just off shore on each side of the puller (Fig. 12 D). The process continues until the seine bag is brought up to the fish chute.

3.4 Removing catch

After the bag reaches the front of the chute, the wings of the bag are drawn along the inside of the fish chute in slots formed by the chute walls and the walls of the lifting apron. As the seine bag is pulled partly up the fish chute, the fish, being crowded, swim over the lifting apron. The apron is then lifted by two men standing on opposite sides, and the fish are dumped into the conveyor. About 45.4 kg (100 lb) of fish can be fed onto the conveyor per lift. Fish deposited in the wire fish baskets located at the exit end of the conveyor are weighed and loaded into the transporting vehicle.

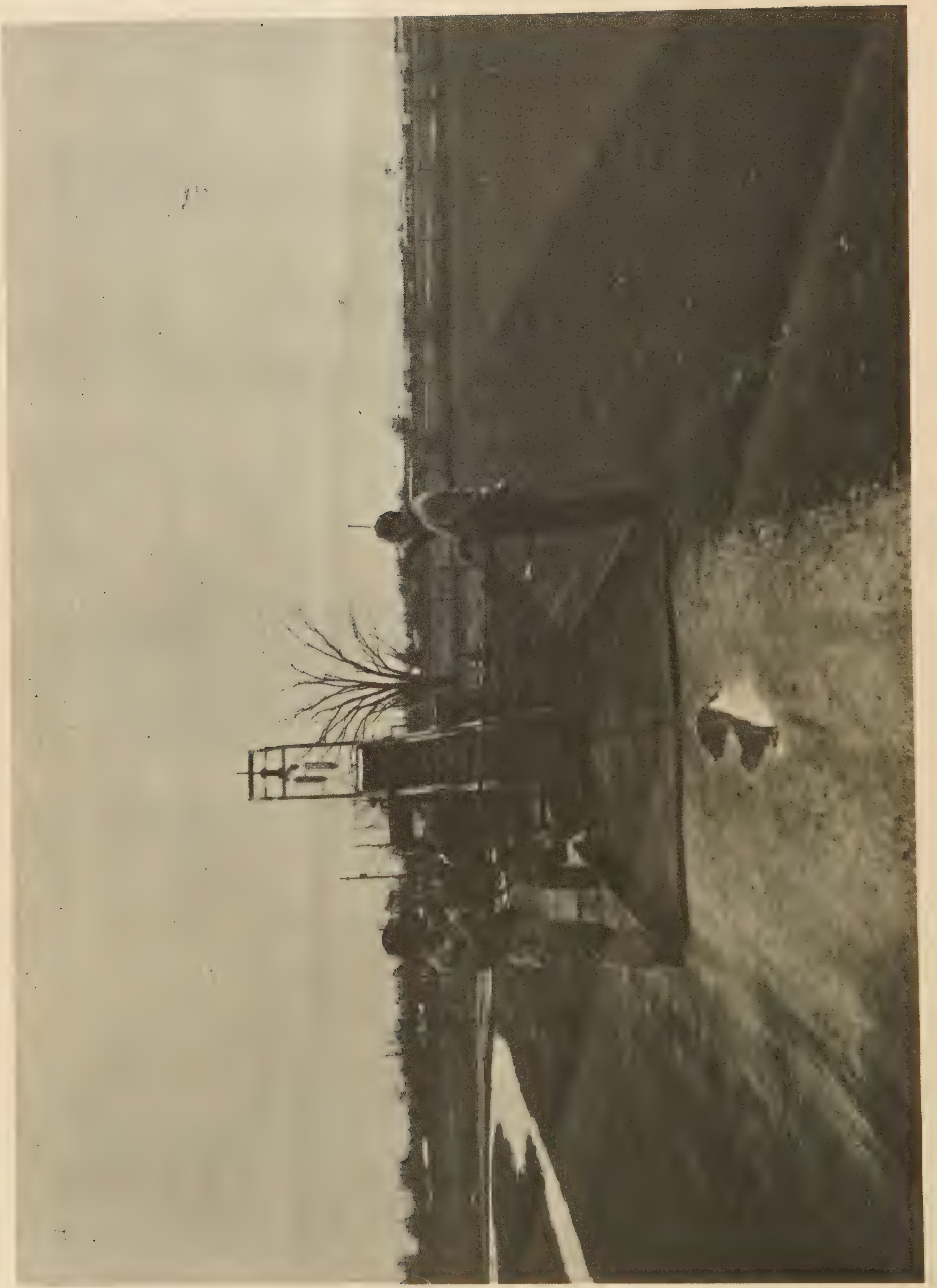

Fig. 9 Modified grain conveyor used to load fish after haul seine has been beached.

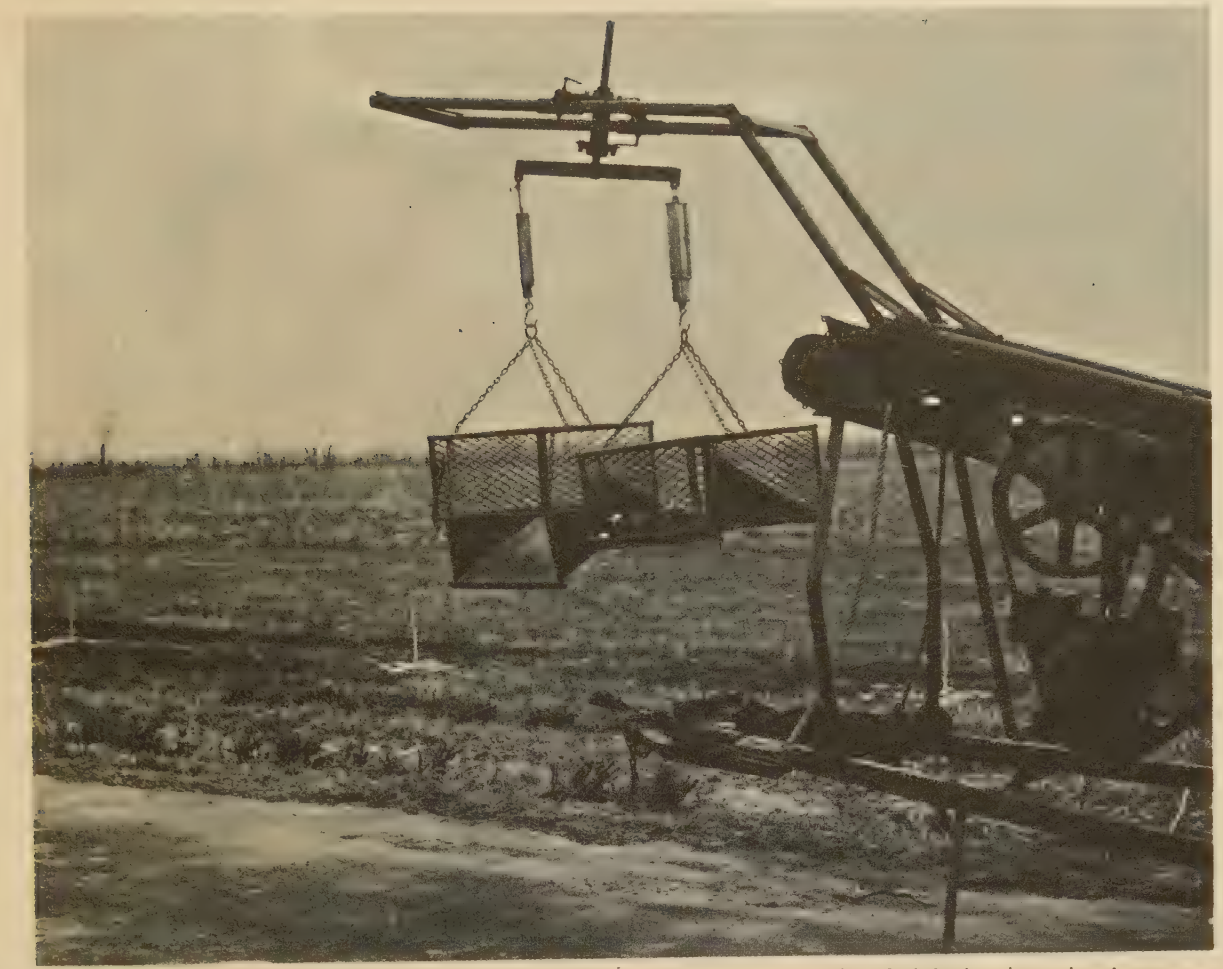

Fig. 10 Revolving fish baskets at exit end of fish conveyor used to weigh catch. Each basket is equipped with a tripping mechanism and 0-160 pound spring scale. As one basket is being filled the other is being weighed and emptied into the loading truck.

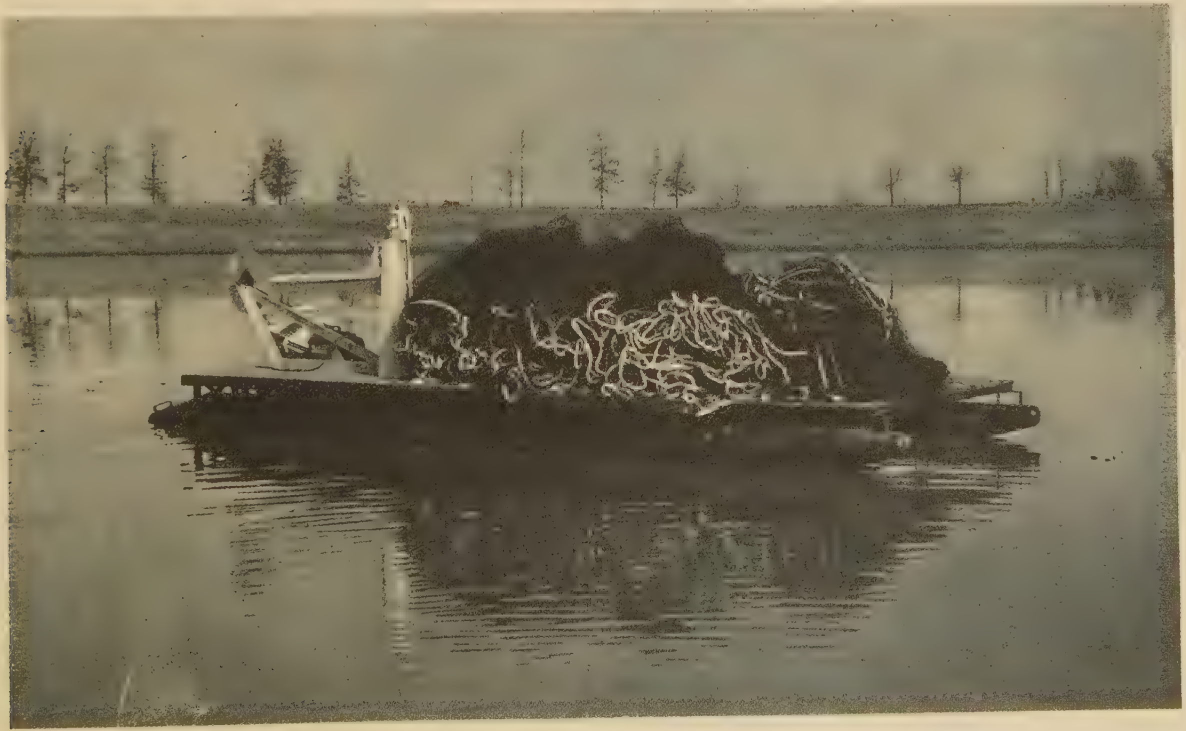

Fig. 11 Nylon haul seine stacked on pontoon barge and ready to set over stern roller

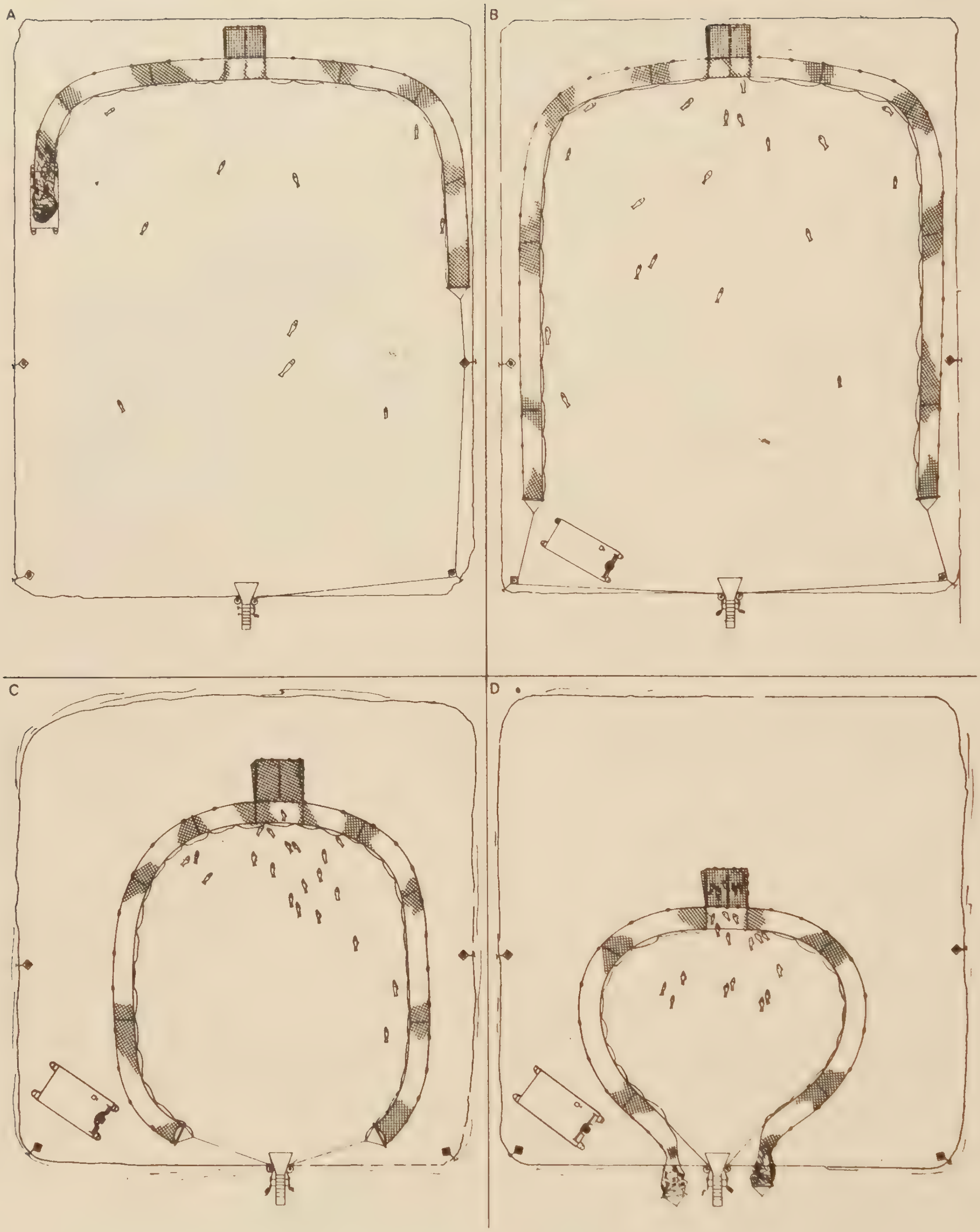

Fig. 12 Operation of farm pond haul seine

Table II

Catch results from 34 mechanized haul seine trials

Trial	Seine length		Haul length		Pond size		Average depth		Percent of pond fished	Species	Est. no. of fish present	Total catch		Total no. caught	Percent caught	Catch per unit of effort (man-hour)		Coded remarks
	m.	ft.	m.	ft.	ha.	ac.	m.	ft.				kg.	lb.			kg.	lb.	
1	566.9	1860	304.8	1000	12.1	30	0.6	2.0	65	Buffalofish	3500	2083.8	4600	1470	42.0	347.5	766.0	a^1,h
2	414.5	1360	304.8	1000	12.1	30	0.6	2.0	65	Buffalofish	2200	635.0	1400	462	21.0	158.7	350.0	a^1,h
3	121.9	400	198.1	650	3.2	8	1.2	4.0	50	Channel catfish	12000	3.2	7	7	0.1	0.0	0.0	a^1,b,h
4	121.9	400	213.3	700	3.2	8	1.2	4.0	60	Channel catfish	12000	367.4	810	625	7.0	66.6	147.0	a^1,b,h
5	140.2	460	190.5	625	3.6	9	1.2	4.0	60	Channel catfish	11700	453.6	1000	1600	14.0	90.7	200.0	a^2
6	201.1	660	190.5	625	3.6	9	1.2	4.0	60	Channel catfish	11700	113.4	250	400	4.0	20.4	45.0	a^2, b,h
7	262.1	860	190.5	625	3.6	9	1.2	4.0	70	Channel catfish	11700	680.4	1500	1500	13.0	13.4	254.0	a^2
8	79.2	260	190.5	625	3.6	9	1.2	4.0	20	Channel catfish	11700	72.5	160	150	1.0	31.7	70.0	a^2,e,h
9	79.2	260	190.5	625	3.6	9	1.2	4.0	20	Channel catfish	11700	12.7	28	39	0.3	7.2	16.0	a^2,e,h
10	79.2	260	152.4	500	1.6	4	1.5	5.0	100	Several species		246.7	544			41.2	91.0	a^2,d,h
11	323.0	1060	190.5	625	3.6	9	1.2	4.0	80	Channel catfish	11700	158.7	350	350	3.0	36.2	80.0	a^2,f,h
12	323.0	1060	190.5	625	3.6	9	1.2	4.0	80	Channel catfish	11400	1814.4	4000	4878	35.0	725.7	1600.0	a^2,i
13	323.0	1060	121.9	400	6.4	16	1.1	3.5	50	Blue catfish	18900	5443.2	12000	12000	64.0	800.6	1765.0	a^1, i
14	323.0	1060	121.9	400	6.4	16	1.1	3.5	50	Blue catfish	6900	181.4	400	400	6.0	51.7	114.0	a^1,i
15	323.0	1060	190.5	625	3.6	9	1.2	4.0	80	Channel catfish	11400	907.2	2000	2500	22.0	283.5	625.0	a^2,i
16	323.0	1060	190.5	625	3.6	9	1.2	4.0	80	Channel catfish	11400	1134.0	2500	3049	27.0	265.3	585.0	a^2,i
17	326.0	1060	190.5	625	3.6	9	1.5	5.0	90	Channel catfish	9790	367.4	810	988	10.0	56.2	124.0	a^2,b,i
18	566.9	1860	359.0	1178	10.1	25	1.2	4.0	80	Several species		680.4	1500		unknown	56.2	124.0	a^2,d,i
19	566.9	1860	365.7	1200	10.1	25	1.2	4.0	100	Several species		381.0	840		unknown	22.6	50.0	a^2,d,i
20	323.0	1060	190.5	625	3.6	9	1.2	4.0	90	Channel catfish	9059	1776.7	3917	4896	54.0	230.8	509.0	a^2,i
21	323.0	1060	190.5	625	3.6	9	0.9	3.0	90	Channel catfish	8142	441.3	973	1187	15.0	54.4	120.0	a^2,i
22	323.0	1060	190.5	625	3.6	9	0.9	3.0	90	Channel catfish	6955	1140.3	2514	3066	44.0	172.8	381.0	a^2,i
23	201.1	660	190.5	625	3.6	9	1.2	4.0	90	Channel catfish	16889	2781.9	6133	5842	35.0	283.5	625.0	a^2,i
24	140.2	460	190.5	625	3.6	9	1.1	3.5	80	Channel catfish	16739	1360.8	3000	6000	36.0	100.6	222.0	a^2,i
25	201.1	660	190.5	625	3.6	9	1.3	4.5	40	Channel catfish	16339	3.6	8	13	0.0	0.4	0.8	a^2,c,i
26	274.3	900	190.5	625	3.6	9	1.1	3.5	0	Channel catfish	16200	0	0	0	0.0	0.0	0.0	a^2,g,i
27	274.3	900	190.5	625	3.6	9	1.2	4.0	60	Channel catfish	16200	1927.8	4250	4292	26.0	267.6	590.0	a^2,i
28	323.0	1060	182.8	600	5.2	13	0.6	2.0	60	Channel catfish	18000	2268.0	5000	3846	28.0	100.2	221.0	a^2,c,i
29	323.0	1060	304.8	1000	5.2	13	0.6	2.0	65	Channel catfish	17445	2358.7	5200	4000	30.0	203.2	448.0	a^2,c,i
30	323.0	1060	152.4	500	2.0	5	0.9	3.0	70	Channel catfish	8500	1020.6	2250	2812	33.0	62.1	137.0	a^2,c,i
31	579.1	1900	762.0	2500	20.2	50	0.9	3.0	60	Channel catfish	75000	11340.0	25000	31250	60.0	281.2	620.0	a^1
32	579.1	1900	365.7	1200	16.1	40	0.9	3.0	70	Blue catfish	26000	9525.6	21000	11500	44.0	371.9	820.0	a^1
33	579.1	1900	304.8	1000	10.1	25	1.1	3.5	90	Several species		1043.2	2300		50.0	43.0	95.0	a^2
34	579.1	1900	457.2	1500	16.1	40	0.9	3.0	75	Blue catfish	24750	15138.9	33375	14511	58.0	573.3	1264.0	a^1
Average	313.9	1034	238.3	782	5.6	14	1.1	3.6	70		14436	1996.2	4401	3973	25.0	169.6	374.0	

a^1/ Irregular shape pond
a^2/ Regular shape pond
b/ Snag encountered
c/ Mud encountered
d/ Number fish in pond unknown
e/ Gear development trials only
f/ Seine wings hauled alternately
g/ Net preservative caused seine to float
h/ Cable puller
i/ Rope puller

Table III

Catch results from 13 manual haul seine trials

Trial	Seine length		Haul length		Pond size		Average depth		Percent of pond fished	Species	Est. no. of fish present	Total catch		Total no. caught	Percent caught	Catch per unit of effort (man-hour)		Coded remarks
	m.	ft.	m.	ft.	ha.	ac.	m.	ft.				kg.	lb.			kg.	lb.	
1	79.2	260	91.4	300	1.2	3	1.1	3.5	100	Blue catfish	4500	1417.5	3150	3130	70	708.7	1575	a^{2}
2	323.1	1060	152.4	500	5.6	14	0.7	2.5	40	Buffalofish		1123.7	2475	616	unknown	151.6	337	a^{1}
3	323.1	1060	152.4	500	5.6	14	1.8	6.0	10	Bass, crappie, bream, buffalofish		141.3	314	516	unknown	11.7	26	a^{1}
4	323.1	1060	152.4	500	6.4	16	1.1	3.5	50	Blue catfish	24000	6750.0	15000	15000	63	597.1	1327	a^{1}
5	91.4	300	152.4	500	1.4	3.5	0.9	3.0	100	Blue and channet catfish	6000	1105.6	2457	2125	35	125.5	279	a^{2}
6	60.9	200	109.7	360	1.6	4	0.9	3.0	20	Buffalofish, bass channel catfish		301.5	670	138	unknown	53.5	119	a^{1}
7	91.4	300	182.8	600	2.5	7	0.6	2.0	90	Blue catfish	9000	79.65	177	177	2	11.2	25	a^{2}
8	60.9	200	121.9	400	0.4	1	0.6	2.0	100	Blue catfish	8823	621.4	1381	1381	16	248.4	552	a^{2}
9	60.9	200	64.0	210	0.7	1.7	0.4	1.5	100	Blue catfish	3792	1143.4	2541	3792	100	114.3	254	a^{1}
10	60.9	200	45.7	150	0.8	2	0.6	2.0	80	Blue catfish	10000	2250.0	5000	5000	50	535.5	1190	a^{1}
11	201.2	660	76.2	250	3.6	9	2.4	8.0	80	Albino channel catfish, buffalofish		729.9	1622	2837	unknown	101.2	225	a^{1}
12	201.2	660	76.2	250	3.6	9	2.4	8.0	20	Buffalofish		99.0	220	404	unknown	3.1	7	a^{1}
13	201.2	660	76.2	250	3.6	9	2.4	8.0	20	Albino channel catfish, buffalofish		99.0	220	404	unknown	18.0	40	a^{1}
Average	160.0	525	104.8	344	2.8	7.1	1.2	4.0	58		9446	908.8	2064	2707	48	205.2	456	

a^{1}/ Irregular shape pond

a^{2}/ Regular shape pond

4 FISHING TRIALS

A total of 47 gear development trials were made with varying lengths, 60.9 to 579.1 m (200 to 1,900 ft) of the haul seine (Tables II and III). Of the total, 34 trials involved the use of mechanized equipment in the operations and 13 trials used manual methods for comparison purposes. Of the 34 mechanized seining operations, the cable-equipped puller was used in 10 fishing experiments and conventional (rope) seine pullers used in 24 fishing trials. The gear was tested 28 times in catfish (Ictalurus punctatus, I. furcatus) ponds (Fig.13), twice in buffalofish (Ictiobus cyprinellus, I. bubalus) ponds (Fig.14), and four times in ponds containing several species.

All mechanized seining trials were conducted in ponds varying in size from 1.6 ha (4 ac) to 20.2 ha (50 ac). The ponds were relatively smooth-bottomed and averaged 1.1 m (3.6 ft) in depth. In all but two cases, the water in the ponds was not drawn down. Most trials were made in ponds of square or rectangular configuration with regular outlines. Seven seine hauls were made in ponds having odd shapes and irregular shorelines.

The average catch from 34 mechanized seining trials was 1996.2 kg (4,401 lb) and 3,973 individual fish. The catches ranged from 0 kg (0 lb) to 15,138.9 kg (33,375 lb) per haul. Average catch per manhour was 169.6 kg (374 lb). An average of 25 percent of the fish present was caught. The latter figure is low due to the fact that 100 percent survival of stocked fish is assumed and in most cases this is not true.

A number of problems encountered were responsible for low catches in some cases. For the most part difficulties involved the seine snagging on bottom obstructions and/or the seine digging into bottom mud (see Table II). Although other difficulties, due largely to minor equipment malfunctions, were encountered, they did not appreciably affect the catches. The data in Table II traces the gaining of experience by the technicians, the solution of major problems and the perfection of this fishing method resulting in larger catches, more kg per manhour, and the ability to fish larger reservoirs in the later trials.

Table III shows the results of 13 fishing trials of the haul seine employing manual methods. Seine lengths used ranged up to 323.1 m (1,060 ft). The ponds fished ranged from 4 ha (1 ac) to 6.4 ha (16 ac) in size. It is important to mention here that the manually seined ponds were generally drawn down for harvesting whereas the mechanized seine operations took place in ponds under full water conditions.

Present seining practices by U.S. fish farmers require ponds to be drawn down in order to concentrate the fish for harvesting. Due to the limitations of the producers' present equipment it is also the general practice not to attempt to completely seine a full pond larger than 1.6 or 2.0 ha (4 or 5 ac) in size.

The average catch for the 13 fishing trials was 908.8 kg (2,064 lb). Catches ranged from 79.6 kg (177 lb) to 6,705.0 kg (15,000 lb).Average catch per manhour was 205.2 kg (456 lb). We repeat that these high averages are due largely to fish being concentrated in collecting basins by draining the ponds.

5 DISCUSSION

The ability of the haul seine to capture approximately 63 percent of the entire buffalofish population in a 15.7 ha (39 ac) pond in two hauls, and 58 percent of the total catfish population of a 16.1 ha (40 ac) pond in one haul (Table II) is significant and indicates the seine to be highly efficient for harvesting farm ponds suitable for this type of fishing. This is especially true when considering that pond shape and condition were not ideal for haul seine use.

Due to its all-nylon construction, the seine proved exceptionally easy to handle during stacking and setting. An added advantage of the synthetic netting materials is resistance to deterioration, allowing the net to be stored wet.

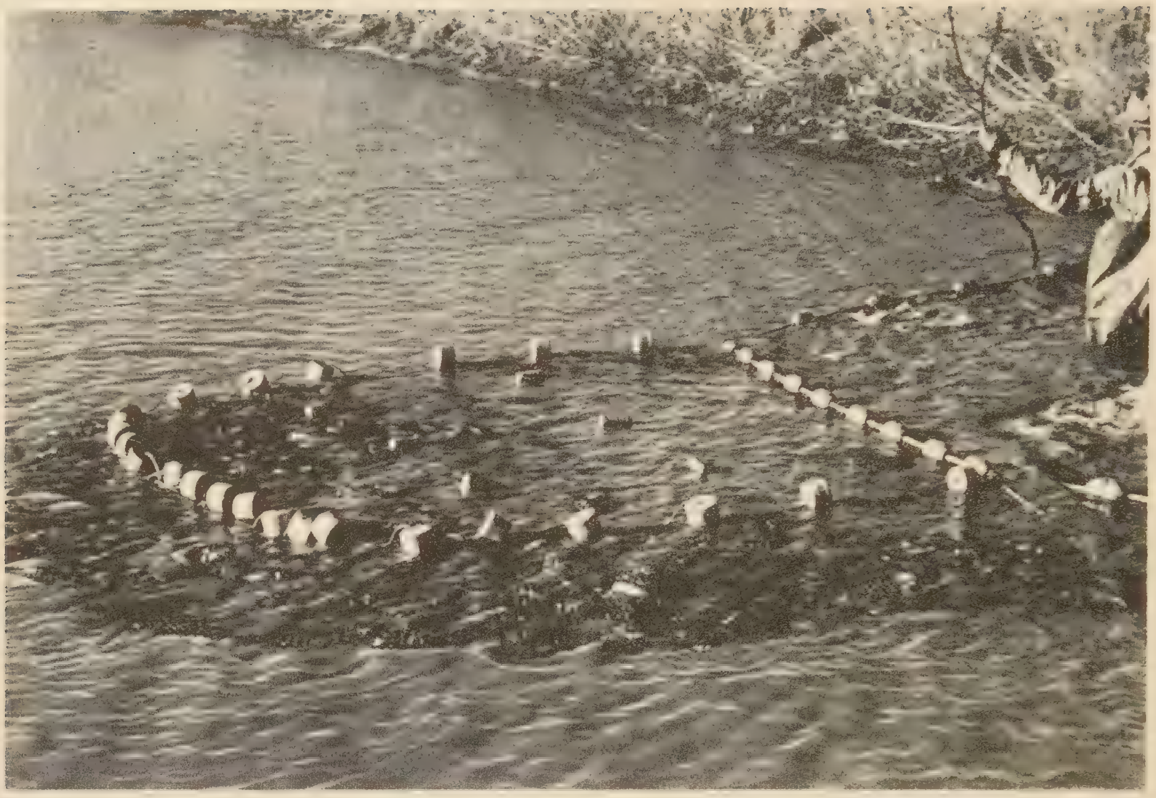

Fig. 13 5443.2 kg catch of channel catfish in seine bag in process of being beached. Catch was made in one haul of mechanized seine from 6.4 ha pond. Note full water conditions of pond which ensures good condition of captured fish.

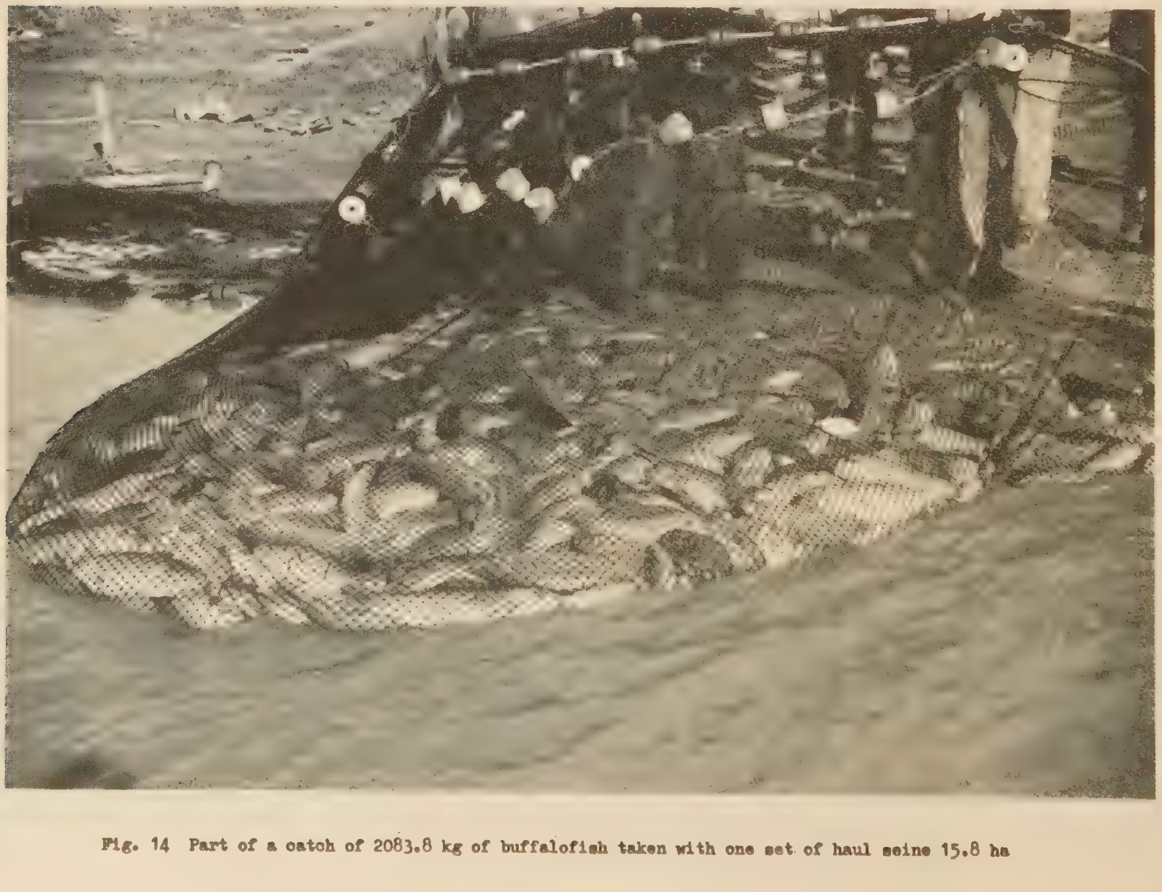

Fig. 14 Part of a catch of 2083.8 kg of buffalofish taken with one set of haul seine 15.8 ha

The present 627.8 m (2,060 ft) seine is capable of harvesting ponds up to about 487.6 m (1,600 ft) wide. Larger ponds could be fished by merely adding sections to the wings and using a more powerful puller. The 10-feet (3.048 m) deep seine can be used in ponds of varying depths up to a maximum of 2.4 m (8 ft).

An average of 4 hauls per 8-hour day could be made with the gear in ponds having ideal seining conditions, thus allowing fish in various amounts to be taken at relatively short notice.

Setting and hauling of the seine up to its maximum length of 627.8 m (2,060 ft) can be accomplished by a two-man crew. This represents considerable savings in manpower compared to conventional methods where a minimum seining crew is composed of six men.

Less handling of fish is involved with the equipment than with conventional methods and fish removed from undrained ponds are in excellent condition and unmuddied.

Three men can efficiently load and weigh the fish employing the conveyor system described.

In addition to the advantages of reduced manpower requirements and better conditions of fish landed, the mechanized seine also eliminates the necessity of drawing down ponds, thus conserving important water supplies.

It is difficult to compare the efficiency of the mechanized haul seine as opposed to manually operated seines for the reason that manually seined ponds are small or are drawn down to concentrate the fish.

Factors affecting the use of the equipment include: (i) design and condition of access approaches to ponds, (ii) overall configuration and design features of ponds, and (iii) presence or absence of woody aquatic plant growth.

6 CONCLUSIONS

Information collected during tests of a mechanized commercial haul seine indicates the equipment to be highly efficient for harvesting flooded fallow rice fields and farm ponds suitable for this type of fishing. Outstanding advantages of the equipment are that fish can be removed from ponds without lowering water levels — resulting in good condition of the fish captured— and the ability to obtain fish at short notice to meet fluctuating market demands. Manpower requirements are also greatly reduced.

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VI/W-1

STANDARDIZATION OF STATISTICAL METHODS IN FISH CULTURE RESEARCH

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Abstract

Attention is drawn to the necessity of discrimination in selection of data in fish culture experiment. Emphasis is made on the formulation of the problem and the design of the experiment. The advantages and disadvantages of randomized blocks, Latin squares, Graeco-Latin squares and Youden squares are discussed. A reduced Latin square and Graeco-Latin square is proposed for 6 x 6 arrangements. The standardization of methods of collecting data - standard length of fish, standard stocking rates, standard sampling times, etc., are urged. The presentation of data is discussed.

NORMALISATION DES METHODES STATISTIQUES EN MATIERE DE RECHERCHE PISCICOLE

Résumé

L'auteur signale la nécessité de choisir avec discernement les données statistiques devant être recueillies lors des expériences de pisciculture. Il s'attache particulièrement à l'énoncé du problème et au plan d'expérience. Après avoir examiné les avantages et les inconvénients que présentent les blocs avec répartition au hasard, les carrés latins, les carrés gréco-latins et les carrés de Youden, il préconise l'emploi d'un carré réduit - latin ou gréco-latin - de 6 x 6. L'auteur signale le vif intérêt que présente la normalisation des méthodes de rassemblement des données (longueurs des poissons, taux de chargement, époques d'échantillonnage, etc.). Enfin, il étudie le mode de présentation des données.

NORMALIZACION DE LOS METODOS ESTADISTICOS EN LA INVESTIGACION EN MATERIA DE PISCICULTURA

Extracto

Se hace observar la necesidad de discriminar en cuanto a la selección de datos en los experimentos piscículturales. Se hace resaltar la importancia de la formulación del problema y el diseño del experimento. Se examinan las ventajas e inconvenientes de los bloques aleatorizados, cuadrados latinos, cuadrados grecolatinos y cuadrados Youden. Se propone para los ordenamientos 6 x 6 un cuadrado latino y un cuadrado grecolatino reducidos. Se insiste en la normalización de los métodos de recolección de datos - longitud típica de los peces, tasas normalizadas de repoblación, fechas normalizadas de muestreo, etc. Se examina también la presentación de los datos.

1 INTRODUCTION

Statisticians complain that far too often masses of scientific data are accumulated on a routine basis without any clear object in view. Research workers in fish culture frequently believe that, because certain routine observations are commonly made in general limnological studies, they must necessarily be made in experiments in fish culture also. Quite often no new knowledge is obtained from these data and time and energy could be better utilized.

It is clear that statistical methods should be applied right from the beginning of an experiment, and not as is so often the case at the end. The experiment must be designed to obtain data which can be analysed statistically. This is best done with the help of a statistician, but as one is not always available in a fish culture research centre, the research worker must acquire adequate proficiency in the design of experiments.

2 FORMULATING THE PROBLEM

Many research papers give the impression that the authors have launched experiments without any clear understanding of the problems they are trying to solve. Formulating the problem properly is the first step, and time spent on this is time well spent.

To better utilize time and energy in carrying out observations it is important to decide the minimum number of variables which must be studied to give adequate data for the solution of the problem under investigation. Equally important is the number of observations which must be made on each variable to give data which have statistical meaning. For instance, comparison between two ponds receiving different treatments may give a useful pointer, but the data may be too limited for statistical analysis.

If ponds are to be constructed specially for the experiments they can be designed to permit several variables to be studied at the same time. If however existing ponds are to be used, it may be possible to vary only one factor at a time, and variables will therefore have to be studied sequentially; it is important in this case to decide the order of priorities. Unlike agricultural experiments, where land can be ploughed and different arrangements of plots designed, very little changes can be effected in ponds and this factor governs the experimental design, since any treatment may give a permanent bias in the properties of the ponds. For example, in Malacca it might have been better if, instead of introducing phosphate, nitrogen and potash, in the first trial, only phosphate had been tested at several levels. This would have demonstrated the over-fertilization effect. Nitrogen and potash could have been introduced in the second or third trials, and it would have been easily found that they were not really necessary.

3 DESIGN OF EXPERIMENT

3.1 The age effect

As soon as a pond is filled with water it undergoes chemical, physical and biological changes, and these are irreversible. The previous history of a pond is therefore of great importance. Ideally, when several ponds have to be used, they should be constructed at the same time and thus be of the same age. Even if this is done it may not be possible to fill them all at the same time and a program must be worked out to reduce the variance due to the time of filling. In Malacca, in the Latin square consisting of 36 ponds of one acre [1] each, three ponds are filled each week, and they are stocked with fish, the fertilizer applied and finally harvested in the same order. Thus all ponds have water, fish and fertilizer for the same length of time. Variations can occur with the time of filling, as can be seen by the gradual shift of plankton succession in Malacca (Malacca, 1963) but this shift has had little effect on the final crop of fish. In Malacca river water was used, but with artesian water even this variable would be eliminated. If ponds cannot be constructed at the same time, experiments should be designed to reduce the variance due to the age of the ponds. If the differences in the latter are wide, the design must permit accurate statistical assessment of variance due to this.

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[1] One acre = 0.405 ha

3.2 The effect of experimental treatment

It is an easy and common approach in fish culture research to await the results of one trial before deciding on the treatment for the next. This method of approach has hidden dangers. Fish ponds are usually shallow, and so the bottom mud may exert a marked effect on the fertility and biota of the overlying water. Any treatment of the pond, particularly the application of fertilizers, may produce a permanent bias in the properties of the bottom mud. If a series of experiments is to be carried out, the sequence should be planned as a whole.

3.3 Testing a hypothesis

There may be no harm in having an idea as to what the outcome of an experiment will be, but the experiment must be designed to test a hypothesis and not to prove it. It may be possible to support a theory by arranging the experiment with a bias, even if this is done unconsciously. For example, ponds with the least water loss due to seepage may be selected for the application of fertilizers, while it might not be considered necessary for controls. Statistical design eliminates this bias, hence the use of randomized plots or Latin squares.

3.4 Standardization of the fish

Unless the optimum stocking rate is the object of the experiment, fish should be stocked at the same rate. In fertilizer trials the ponds should be of the same size and have the same number of fish in each. In a fertilizer trial in the Philippines (Padlan, 1956) the validity of the conclusion that the fertilizer used was beneficial was made doubtful because 2,500 fish were stocked in the pond with fertilizer as against 1,000 in the control. If the crop of fish in the fertilized pond (484 kg) is divided by 2½, it is little different from the crop in the unfertilized pond (180 kg); the increased crop in the former might easily have been due to the larger number of fish. Where possible, the fish should be of the same origin, preferably the same parentage, and at least the same age. In Malacca each row of the Latin square received fish from the same stock, so that each treatment had fish of the same age and origin. A similar arrangement could be used in randomized plots.

3.5 The size of the experimental ponds

It has been shown (Chen and Prowse, in press; Malacca, 1963; Prowse, 1963; 1964 and in press) that the growth rate of fish increases with increase in the area of pond; the "living space" effect has been shown to be a real one. There is also evidence (Brockway, 1950; Kawamoto and Nakarishi, 1957; Chen and Prowse, in press) that small ponds may inhibit the growth rate of fish. Ponds should therefore be as large as possible, and all of the same size, except in studies of the effect of size of ponds.

3.6 Simplicity of design

Research workers, especially when they are new to the field, often want to try out complex and sophisticated techniques when an experiment of much simpler design may give the same result with far less effort. It is advisable to start from the simple and work up to the complex rather than the reverse; complexities introduced early are difficult to eliminate later. There are often ways of simplifying an experiment and at the same time eliminating unknown variables. The divided pond technique in Malacca is an example. Ponds divided into 1/3 and 2/3 can be used to test the living space effect, while ponds divided down the middle could be used to compare the growth rate of two different strains of fish, such as of *Tilapia mossambica*.

When known variables are to be considered, it is wise to limit the number of variables to be studied at one time. In industry it is often possible to have many variables, but the aim of the statistical study is to give greater control, and frequently much is known to suggest the result. In fish ponds there are far too many unknowns, particularly interactions between fish and fish, fish and plankton, soil and water chemistry and pond biota. It is therefore unwise to mix different kinds of variables. Fertilizer studies are better kept separate from stocking rate studies, particularly if several species of fish are involved.

4 STATISTICAL DESIGNS

The most important variable in fish ponds is that due to uneven soil fertility, slope, drainage, etc. There are several statistical designs to reduce the error due to such variability.

4.1 Randomized blocks

In this the total area is divided into compact blocks, each containing the same number of ponds, which should be rectangular and lying side by side. The number of ponds within each block determines the number of replications for each treatment. Thus, if there are five ponds in each block, five different fertilizer treatments could be tested. The treatments are assigned to the ponds in each block at random, using random numbers. Defects are that the number of replications should be large, not less than five. This means a large area of land must be converted to ponds for this purpose.

4.2 The Latin square

Variations in the soil usually occur in strips or blocks. The error due to these variations can be reduced by using a Latin square design. In this the ponds are arranged in a square pattern, the number on each side being the number of treatments to be tested. Each treatment occurs only once in each horizontal and vertical row, so that errors are reduced in two directions at right angles.

A typical 5 x 5 square is:

B C E D A

E A C B D

A B D E C

D E A C B

C D B A E

It can be mathematically shown that the number of such squares with side n is (factorial n)^2. Usually a square is chosen at random from tables, but not all squares are equally suitable, as the following shows:

A B C D E

B C D E A

C D E A B

D E A B C

E A B C D

This is formed by shifting one letter from the end of each row, but it is obvious that treatments lie in diagonals. Any bias in soil in this direction would have a marked effect on the results. In Malacca a 6 X 6 Latin square was chosen (but not by the author):

A	B	C	D	E	F
D	F	A	B	C	E
C	A	E	F	D	B
E	C	F	A	B	D
B	E	D	C	F	A
F	D	B	E	A	C

Even here there are too many diagonal groups - four 'F's, three 'D's and three 'B's. Fortunately statistical analysis has shown that there is no bias of the soil in this direction, but it might have been otherwise.

A little shifting of rows could improve the design:

F	D	A	B	C	E
A	C	E	F	D	B
C	E	F	A	B	D
E	B	D	C	F	A
D	F	B	E	A	C
B	A	C	D	E	F

Even this is not perfect and it is difficult to find ideal solutions for a 6 X 6 Latin square. For this and other reasons a 5 X 5 or a 7 X 7 Latin square would have been preferable

4.3 Graeco-Latin squares

If we consider the two Latin squares:

A	B	C	D	E
B	C	D	E	A
C	D	E	A	B
D	E	A	B	C
E	A	B	C	D

and

α	β	γ	δ	ε
ε	α	β	γ	δ
δ	ε	α	β	γ
γ	δ	ε	α	β
β	γ	δ	ε	α

one can be imposed on the other to form the Graeco-Latin square:-

Aα	Bβ	Cγ	Dδ	Eε
Bε	Cα	Dβ	Eγ	Aδ
Cδ	Dε	Eα	Aβ	Bγ
Dγ	Eδ	Aε	Bα	Cβ
Eβ	Aγ	Bδ	Cε	Dα

It will be noticed that no combination of Latin and Greek letters occurs more than once. Latin squares which can be superimposed on each other are orthogonal to each other. It is possible to have a third, fourth, etc. squares superimposed in this way, which would permit a different variable for each Latin square. In general if p is a prime number as the side, there are $p - 1$ orthogonal Latin squares and therefore $p - 1$ variables can be tested at the same time. Thus a 5 X 5 square permits 4, while a 7 X 7 square permits 6 variables. Unfortunately, if the side is $4n + 2$ orthogonal squares are not possible and only one variable can be tested. Thus it was unfortunate that the designers of the Institute in Malacca chose a 6 X 6 Latin square.

The ponds themselves need not be square, only the pattern of arrangement, but all the ponds must be of the same size and shape and equidistant from one another.

4.4 Youden squares

In randomized blocks each block must be large enough to include one of each treatment, but it may happen that we wish to test more treatments than we have ponds in each block. In this case a Youden square is a useful device. If we have blocks of four ponds and we wish to test five treatments we could use the pattern:

	Blocks				
Treatments	A	B	C	D	E
	D	E	A	B	C
	B	C	D	E	A
	E	A	B	C	D

In each block a single treatment has been omitted, a different one in each case. This is in effect a Latin square with the bottom line omitted, and this is an easy way of forming a Youden square. We could leave out more rows; in general if there are p blocks and $p - n$ ponds we can form a Youden square by leaving out the bottom n rows from a p X p Latin square if we wish to test p treatments.

4.5 Reduced Latin squares

The principle of leaving out rows can be extended in two directions and this can make a 6 X 6 Latin square more versatile, regarding it as a 7 X 7 square with one vertical and one horizontal line omitted.

$$\begin{array}{cccccc|c}
A & B & C & D & E & F & G \\
B & F & E & G & G & A & D \\
C & D & A & E & B & G & F \\
D & C & G & A & F & E & B \\
E & G & B & F & A & D & C \\
F & A & D & C & G & B & E \\
\hline
G & E & F & B & D & C & A
\end{array}$$

This can be extended to a Graeco-Latin square so that two variables could be tested in a 6 X 6 square.

A1	B2	C3	D4	E5	F6	G7
B3	F7	E6	G1	C4	A2	D5
C7	D1	A5	E2	B6	G4	F3
D6	C5	G2	A3	F1	E7	B4
E4	G6	B1	F5	A7	D3	C2
F2	A4	D7	C6	G3	B5	E1
G5	E2	F4	B7	D2	C1	A6

It must be noted that while six of each variables have been omitted twice, i.e. horizontally and vertically, one of each A and 6 have been omitted once. For this reason, in the statistical analysis the omitted treatments must be included as null treatment and null crops, when calculating variance.

5 COLLECTION OF DATA

Observations during experiments can be of two kinds, descriptive ones, often of great value in giving a general picture, and those involving measurement. The latter form the data for statistical analysis. Unfortunately, if the numerous research papers on fish culture are any indication, the collection of data frequently leaves very much to be desired.

5.1 The fish

Measurements of fish usually involve the length, depth and weight. Various types of length measurements are used, some to the tip of the tail. Since the tail can be easily damaged, it is preferable to use the standard length, which is the length from the tip of the upper jaw to the midpoint of the junction of the fleshy peduncle with the tail. Depth should be maximum depth, and it is useful to state how far this is along the body line, either in scale numbers or more easily as a proportion of the standard length from the tip of the jaw. In all cases the method of measuring should be stated. Measurement of weight should present no difficulties.

When measuring the total crop of fish, the fish should be harvested after the same period of time after stocking. The growth rate of a fish is not uniform throughout its life, and fingerlings grow much faster than adults, since they have a smaller maintenance requirement. It is not valid to extrapolate growth rates from shorter intervals, as has been done in some research papers. If samples of fish are being examined for comparative growth rates, the intervals of time between fishing should be the same for all ponds and for all fish stocks.

Ideally all the fish in the pond should be measured for growth rates, but this is often not possible. In general not less than 100 of each species from each pond should be measured; for statistical reasons it is preferable that at least one-third is measured; where possible this limit should be maintained. In all experiments containing the same populations the sample size should be the same. When comparing stocking rates the sample should contain the same proportion of the total population, unless this proportion falls below 100, when all should be measured. A similar criterion should be used in the "living-space" experiment. In any case the number of the total population and the number in the sample should be clearly stated. Varying numbers and proportions can be analyzed statistically, but the error may be greater and the analysis more complex.

5.2 Chemical and physical measurement

The main object of fish culture is the production of fish and one must never lose sight of this fact. In general limnology detailed surveys are often made of lakes, at various depths and over a period of time. As useful as this is in limnology, in fish culture research we have not the personnel or time for such elaborate studies, nor are they necessarily relevant to the final object, the production of fish. In practice, one or two sampling points are chosen, based on an initial survey of the pond. Having chosen a sampling site we should adhere to this throughout the experiment.

The time of day at which samples are taken is important, particularly if oxygen, pH, alkalinity and temperature are measured since these fluctuate throughout the day. Twenty-four hour cycles are of interest, but may not be sufficiently relevant to fish production to warrant the time spent. If data are to be statistically analyzed, they must be sufficiently detailed and ready for analysis as soon as possible. If it is necessary to wait a long period for someone to try and make sense of it, it is hardly worth the effort of collection. Staff is often limited, and with a large number of ponds, this limits the number of samples per pond at any one time. Sunshine, cloudiness, and temperature all affect the results, so if the number of ponds is large there may be appreciable differences between the first and the last, due simply to the lapse of time. The situation is worse if ponds in different areas are being sampled on the same day. Measurements of pH and oxygen so often quoted in papers may have little meaning because they are taken at the wrong time of day. They may serve as rough comparisons between ponds but cannot be analyzed statistically. Measurements of oxygen just before dawn, when the values are a minimum, have value for indicating danger levels to fish.

Research papers often list estimates of dissolved phosphate, potassium and nitrogen, but it is reasonable to ask whether such figures have any real meaning. They may have value in large lakes, or in unfertilized smaller bodies of water, but in fish ponds where fertilizer treatments can radically alter conditions, such isolated measurements have little value. Phosphate rapidly disappears from the water, being absorbed by phytoplankton, macrophytes and the bottom mud. There will therefore be a marked difference between estimates immediately after fertilization and at a later date. In fertilizer trials the chemical analyses of water (and if possible plankton, macrophytes and mud) should be planned as a complete and integral part of the program and the methods should be standardized - sampling site, time of day, method of sampling and methods of estimation. The chemical analysis should be undertaken by a chemist specifically for this work. It still does not necessarily follow that the chemical analyses will show any clear relation with the fish crop.

5.3 Plankton

Although it is customary to take phytoplankton and zooplankton samples throughout fish culture experiments, it is still necessary to be clear what any estimates if any actually mean. Phytoplankton in fish ponds is dense, often forming scums. Wind may pile up these algal scums, to one end, particularly *Microcystis aeruginosa*, *Euglena sanguinea*, *Botryococcus braunii*, etc. Cyanophyceae with gas vacuoles, and mucilaginous green algae which can trap oxygen, may rise during the day and sink at night. Since time will not permit sampling at several points the sampling points should be at the end away from the algal scums. An accurate estimate cannot be obtained, but a picture of the relative change with time is possible.

Zooplankton often shows diurnal vertical movements, and much which applies to phytoplankton applies to zooplankton also. The sampling points, time of sampling and the intervals of sampling should be fixed. Methods of estimating the zooplankton should be consistent, and if it is necessary to dilute for counting, the dilution should be stated. Units, whether as single cells, filaments or colonies should be stated, and these units should be consistent.

With small samples from large populations, variations of as much as 100 percent may occur through sampling error. It would therefore be unwise to regard an increase from say 500 to 900 organisms per ml as being significant, without other evidence to support it. In general, changes within the same logarithmic paper should be regarded as not significant. A change from 500 to 5000 could be regarded as significant.

Extrapolations from plankton measurements to the annual production are of doubtful value. This is particularly so in fish ponds, where the high grazing intensity of the fish markedly affects the standing crop, so that we have no measure of the true primary production. Although pictures of the relative changes can sometimes be deduced, it would be unwise to attempt the analysis of such data statistically. Primary production can be measured reasonably accurately by using dark and light bottles or C_{14}, but this is total primary production. Since the ability of different algae to be digested by fish varies, we have no measure of how much of the total primary production is utilized by the fish. Plankton counts of genera and species, together with a study of which species are digested may give a general picture of the production of the pond, but such data cannot be analyzed statistically.

6 PRESENTATION AND INTERPRETATION OF DATA

Proper presentation of data is of special importance in fish culture research. Fantastic annual fish crops are often claimed, but on close examination these appear to be extrapolations of growth rates of small fish, hardly bigger than fingerlings, taken over a short period of time. The growth rate of a fish is not a straight line graph which can be extrapolated in this way. The maintenance ration for small fish is low, so that most food consumed goes into growth, whereas the maintenance ration of large fish is much greater. It is possible to get a larger crop of small fish than of fish of edible market size, but the proportion of utilizable material may be greater in the larger fish. Whenever crops of fish are the object of the experiment, it should be extended until the fish reach edible size. In Malacca this is often six months in growth, but elsewhere it may be longer. Standard and consistent measurements should be used and stated. The size of pond should always be stated as well as the stocking rate.

Chemical data presented should be relevant to the experiment. There is little point in making long lists of chemical analyses and repeating these in words, when they have little connection with the experiment. Data should be concise and to the point.

This applies equally to plankton. Long lists of species and genera often have little relevance to the experiment. Significant fluctuations are better treated graphically and the attention drawn to the fluctuations, where possible with conclusions. It should be relevant to the treatment of pond or some important feature in the experiment. It may not be possible to treat these data statistically, but if given with other relevant data, such as the feeding habits of the fish, they may enable interpretation of data statistically.

No attempt has been made in this paper to deal with methods of statistical analyses, since these are available in all standard textbooks. Instead this paper has concentrated on the collection of data, with the various pitfalls to be avoided. If many of the points seem obvious, judging from many research papers they may be so obvious that they are neglected by many research workers.

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STANDARDIZATION OF CHEMICAL ANALYSES FOR WATERS AND POND MUDS

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STANDARDIZATION OF CHEMICAL ANALYSES FOR WATERS AND POND MUDS

Dissolved oxygen: It is recommended that either the azide or sulphamic acid modification of the Winkler method be used for most pond waters. In the presence of excessive wastes, high iron or other interfering materials, Ohle's iodine difference modification should be used. The polarographic method is useful for rapid routine analysis when calibrated against the Winkler method at different temperatures and for waters of different salinity.

Free carbon dioxide: It is recommended that this determination be made by titration with standard NaOH or Na_2CO_3 to the phenolphthalein end point (pH 8.3) and be reported as ppm CO_2.

Total alkalinity: It may be defined as the total titratable bases in water. It is recommended that it be determined by titration of a water sample by standard HCl or H_2SO_4 to the following end points.

pH 5.1 when total alkalinity is 30 ppm as $CaCO_3$
4.8 when total alkalinity is 150 ppm as $CaCO_3$
4.5 when total alkalinity is 500 ppm as $CaCO_3$

Intermediate values of the end point can be estimated by interpolation.

Total alkalinity can be approximated by titration to the methyl orange end point and is occasionally called methyl orange alkalinity. It should be reported as ppm $CaCO_3$.

Analytical methods are given for separation of total alkalinity in bicarbonate and OH alkalinities. Bicarbonate alkalinity appears biologically more significant than total alkalinity.

Total hardness should be determined by EDTA titration to chrome black T end point, and total calcium by EDTA titration using ammonium purpurate indicator.

Hydrogen ion concentration should be determined only by electrometric glass electrode. Colorimetric methods are too inaccurate for use in pond waters.

Bottom muds: pH should be determined by using a standard electrometric glass electrode.

Lime requirements should be determined by loss in pH following mixture of a standard buffer mixture with the dried soil sample.

NORMALISATION DES METHODES D'ANALYSE CHIMIQUE DES EAUX ET DES VASES DES ETANGS

Résumé

Oxygène dissous: Pour la plupart des eaux d'étang, il est recommandé d'utiliser l'une des deux variantes de la méthode de Winkler (azide ou acide sulfamique). Lorsque l'on se trouve en présence de déchets excessifs, d'une teneur élevée en fer, ou d'autres matériaux gênants, il convient d'utiliser la méthode d'Ohle (modification de la différence en iode). La polarographie est utile pour les analyses rapides de routine lorsqu'elle est étalonnée avec la méthode de Winkler pour différentes températures et divers degrés de salinité.

Gaz carbonique libre: Pour déterminer cet élément, il est recommandé d'effectuer un titrage avec du NaOH ou du Na_2CO_3 standard en présence de phénolphtaléine (point de virage pH 8,3) et d'exprimer les résultats en ppm CO_2.

Alcalinité totale: On peut la définir comme étant la quantité totale de bases titrables dans l'eau. Pour la déterminer, il est recommandé d'effectuer le titrage d'un échantillon d'eau avec du HCl ou du H_2SO_4 standard aux points de virage suivants:

pH 5,1 lorsque l'alcalinité totale est de 30 ppm, exprimée sous forme de $CaCO_3$
4,8 lorsque l'alcalinité totale est de 150 ppm, exprimée sous forme de $CaCO_3$
4,5 lorsque l'alcalinité totale est de 500 ppm, exprimée sous forme de $CaCO_3$

Les valeurs intermédiaires du point de virage peuvent être estimées par interpolation.

Une approximation de l'alcalinité totale peut se faire par titrage au méthyl orange; on parle alors parfois d'alcalinité méthyl orange. Les résultats doivent être exprimés en ppm de $CaCO_3$.

Des méthodes analytiques sont indiquées pour distinguer, dans l'alcalinité totale, les bicarbonates alcalins, les carbonates alcalins et les hydroxydes alcalins. La teneur en bicarbonates alcalins paraît avoir une importance biologique plus grande que l'alcalinité totale.

La dureté totale doit être déterminée par titrage à l'EDTA au point de virage du noir au chrome T, et le calcium total par titrage à l'EDTA en utilisant comme indicateur le purpurate d'ammonium.

La concentration en ions hydrogène doit être déterminée par électrométrie (électrodes en verre). Les méthodes colorimétriques sont trop imprécises pour être utilisées avec les eaux d'étang.

Vases de fond: Le pH doit être déterminé par la méthode électrométrique standard (électrodes en verre).

Les besoins en chaux doivent être déterminés par la perte de pH résultant de l'adjonction d'un mélange tampon standard avec l'échantillon de sol séché.

NORMALIZACION DEL ANALISIS QUIMICO DE LAS AGUAS Y LOS FANGOS DE LAS LAGUNAS Y CHARCAS

Extracto

Oxígeno disuelto: Se recomienda que, para el análisis de la mayoría de las aguas de las lagunas y charcas, se utilice la modificación de la azida o el ácido sulfámico del método de Winkler. Cuando estas aguas contengan una cantidad excesiva de restos, mucho hierro, u otras materias que estorben el análisis, deberá utilizarse la modificación de Ohle de diferenciación con el yodo. El método polarográfico es útil para los análisis ordinarios rápidos cuando se le corrige con relación al método de Winkler a diferentes temperaturas y para las aguas de distinta salinidad.

Bióxido de carbono libre: Se recomienda que esta determinación se haga por titulación con NaOH o Na_2CO_3 normales hasta el punto final de pH 8,3, usando la fenolftaleína como indicador, y que los resultados se expresen en ppm de CO_2.

Alcalinidad total: Se la puede definir como el total de bases titulables que hay en el agua. Se recomienda que la alcalinidad total se determine por titulación de una porción de agua con HCl o H_2SO_4 normales hasta los siguientes puntos finales:

pH 5,1 cuando la alcalinidad total sea 30 ppm expresada en $CaCO_3$

4,8 cuando la alcalinidad total sea 150 ppm expresada en $CaCO_3$

4,5 cuando la alcalinidad total sea 500 ppm expresada en $CaCO_3$

Pueden calcularse valores intermedios del punto final por interpolación.

La alcalinidad total puede determinarse en manera aproximada por titulación hasta el punto final empleando anaranjado de metilo como indicador, por lo que, a veces, recibe el nombre de alcalinidad al anaranjado de metilo. Esta alcalinidad debe expresarse en ppm en $CaCO_3$.

Se exponen métodos analíticos para la separación de la alcalinidad total en alcalinidad bicarbonato, carbonato y oshidrilo. La alcalinidad bicarbonato parece que es biológicamente más significativa que la alcalinidad total.

Dureza total: La dureza total deberá determinarse por titulación con ácido etilendiaminotetracético hasta el punto final, utilizando negro cromo T como indicador, y el calcio total, por titulación con ácido etilendiaminotetraacético, usando purpurato de amonio como indicador.

Concentración de iones hidrógeno: Esta concentración se determinará únicamente mediante electrodos de vidrio electrométricos. Los métodos colorimétricos son demasiado imprecisos para usarlos en el análisis de las aguas de las lagunas y charcas.

Fangos del fondo: El pH se deberá determinar mediante un electrodo de vidrio electrométrico normal.

Las necesidades de cal habrán de determinarse evaluando la disminución del valor del pH después de mezclar una mezcla reguladora normal con la porción de suelo seco que se analiza.

The principal analyses upon which standardization of analytical methods and/or methods of reporting the results would appear desirable in water are: oxygen, free CO_2, alkalinity, hardness, calcium and pH; in bottom soils, pH, and lime requirement.

1. ANALYSES OF WATERS

1.1 Dissolved oxygen

1.1.1 Chemical analysis

Water sample must be taken in a manner to prevent loss of gases or aeration of the sample. Since waters may contain substances such as nitrites or ferric iron, which can release iodine from KI giving high results, or ferrous iron, sulphites and organic matter, which cause low results by absorption of free iodine, most accurate results are obtained by prompt completion of the analysis.

Where substances are suspected to be interfering with accuracy of the analyses, it is recommended that Ohle's (1953) iodine difference modification of the Winkler method be used. This procedure corrects for the presence of materials causing either high or low results. A modification of this method is given in the Appendix to this report.

Where interfering substances do not occur, the azide or sulphamic acid modifications prevent interference from nitrites, which are present in all waters containing fish. The latter method also may be found in the Appendix.

1.1.2 Polarographic method

This method uses a platinum or gold electrode and a silver-silver oxide reference electrode bathed in a suitable electrolyte (KOH, KCL) and enclosed by a 0.5 mil teflon membrane. Oxygen passes through the membrane, is reduced by the platinum or gold electrode and a current flows to the silver electrode; this current is measured in microamps. Since passage of oxygen through the membrane is a function of its tension, this method measures tension, not ppm dissolved oxygen. Consequently, the meter must be calibrated against the Winkler DO determination for waters of different salt contents and a factor is then calculated to convert microamps to ppm DO (Ohle, 1953; Kanwisher, 1959; Sneed and Dupree, 1963).

Polarographic oxygen meters are satisfactory for rapid routine determinations of DO when calibrated against the Winkler results on the same waters. The polarographic method usually underestimates DO in supersaturated water.

1.1.3 Reporting results

The results of all analyses should be reported as ppm DO. It would be desirable to have the water temperature recorded from the same depth at which the water sample was taken.

1.1.4 Interpretation

The minimum DO in which most pond fishes can live for extended periods at rest is 1 ppm. For fish undergoing activities of spawning or feeding, approximately 3.0 ppm DO is needed. For limited periods, pond fishes enter and feed in areas with DO as low as 0.3 ppm.

1.2 Free carbon dioxide

Carbon dioxide is present in the air at concentrations of approximately 3 parts per 10,000. Consequently, pure water at 1 atmosphere air pressure at 25°C contains only 0.4 ppm free CO_2 when in equilibrium with CO_2 in the air. In deep waters, much higher CO_2 concentrations are built up because of release of CO_2 by respiration and decomposition.

1.2.1 Chemical analysis

The pH of the water sample should first be determined. Acidity from free CO_2 can seldom make the water more acid than 5.5. More acid waters should be suspected of containing strong mineral acids.

In this case, titration of water samples to the phenolphthalein endpoint (8.3) with standard NaOH or Na_2CO_3 should be made on two samples. One sample should be brought just to boiling while stirring to drive off free CO_2 before titration and the other titrated without heating. The difference between titrations (unboiled-boiled) should be expressed as free CO_2. The titration of the unboiled sample should be expressed as total acidity. If water is more alkaline than 5.5, the unboiled water titre may be expressed as free CO_2.

1.2.2 Reporting results

The results should be reported as ppm CO_2. The titre on the boiled water sample should be expressed in ppm as H_2SO_4 since worldwide sulphuric acid is the most common strong acid occurring free in natural unpolluted waters.

1.2.3 Interpretation

Concentrations of free CO_2 in excess of 15 ppm are detrimental to pond fishes. Those fishes able to gulp air at the surface can survive 100 ppm, whereas many of those unable to gulp air find difficulty in breathing at 30 ppm and may die at slightly higher concentrations.

1.3 Total alkalinity

This is best defined as the total of titratable bases in a water. The titration is normally made to the methyl orange endpoint or to a pH between 4.5 and 4.0 with standard HCl or H_2SO_4. Consequently, the bases titratable are those combined with carbonate and/or bicarbonate ions, or in rare cases with some other weak acid, or with OH. The last is seldom present except in polluted waters. There is little that is standard about nomenclature or methods of expressing this value. It has been called alkalinity, total alkalinity, methyl orange alkalinity, or alkaline reserve, and is sometimes erroneously considered to be the same as hardness. It is variously expressed as $CaCO_3$ equivalent, as bicarbonate and/or carbonate ions, as cc. N/1 HCl per litre, or as cc. 0.1 HCl per 100 cc sample. (Schäperclaus, 1966 ; Ellis, *et al.* (1948), Swingle (1964)). It is suggested that the value be called "total alkalinity" and the endpoints be at the following pH values;

pH = 5.1 when total alkalinity is 30 ppm as $CaCO_3$
= 4.8 when total alkalinity is 150 ppm as $CaCO_3$
= 4.5 when total alkalinity is 500 ppm as $CaCO_3$

The titration can most accurately be made using a pH electrode to determine the endpoint. Two indicators are suitable for use when extreme accuracy is not necessary; methyl orange which gives an orange endpoint at approximately 4.5 and Xylene cyanole-methyl orange with a grey endpoint at approximately the same pH.

1.3.1 Reporting results

It is recommended that total alkalinity be expressed as ppm $CaCO_3$ equivalent.

1.3.2 Interpretation

Total alkalinity has been taken as a good measure of productivity of waters by several authors (Schäperclaus , 1966, Hickling, 1962) as follows:

Total alkalinity as		Pond cultural significance
cc. N HCl per litre	ppm $CaCO_3$ equivalent	
Zero	Zero	Water strongly acid, unusable
0.1 - 0.5 cc.	10 - 50	Alkalinity very low, danger of fish dying, pH variable, CO_2 supply poor, water not very productive
0.5 - 2 cc.	50 - 200	pH variable, carbon dioxide supply medium, productivity medium
5 cc. +	500 +	Rarely found, pH very constant, productivity alleged to decline but not proven so far. Health of fish not endangered.

Total alkalinity may be the result of the cations Ca, Mg, Na, K, NH_4, and Fe combined as carbonates and/or bicarbonates, or rarely as OH. The possibility of OH being present in titratable amounts may be dismissed except in polluted waters or rarely in surface waters during mid-afternoon with very intense photosynthesis. While certain phytoplankton and higher aquatic plants can use carbonate at a very slow rate in photosynthesis, in most waters it is of little importance as a source of photosynthetic carbon.

The above system of classification for suitability of water for pond culture may possibly hold where modern practices of liming and fertilization will not be used and where the soils are located in areas of moderate to heavy rainfall. Under such conditions, often total alkalinity is largely calcium and magnesium salts and this is more or less equivalent to hardness. However, it is not the hardness or alkalinity alone that is responsible for high natural fertility, but the fact that high calcium content of soils is usually correlated with a high content of phosphate, nitrogen, and other plant nutrients. In dry land areas, alkalinity may be largely composed of carbonates of sodium and potassium and would be no indicator of natural productivity. Also, where water supplies come from springs or wells in contact with marine deposits, sodium and potassium may make up a considerable part of total alkalinity. Such waters, of course, would have a fairly high pH ranging from 8 to 10 or more.

Many productive rivers and fish ponds fall within the second class of waters with total alkalinity equivalent to 10 to 50 ppm $CaCO_3$.

The cyclic carbon principally useful in photosynthesis is that present as free CO_2 and half of that present as bicarbonate. Where plankton is abundant, by mid-afternoon in the zones of active photosynthesis often all free CO_2 has been used plus most or all of that released from the bicarbonates as the CO_2 tension decreases,

$$Ca(HCO3)_2 \rightarrow CaCO_3 + H_2O + CO_2,$$

and the pH may have risen to 9.5 or in exceptional cases to 10.0.

Under certain conditions it would appear that bicarbonate concentration might be a better measure of biological productivity than would either carbonates or total alkalinity. By titration of water samples with standard HCl first to the phenolphthalein endpoint and then on to the methyl orange endpoint, a biologically satisfactory separation of bases combined as carbonates from those combined as bicarbonates may be made.

1.3.3 Bicarbonate-Carbonate-OH alkalinity

Methods for these analyses by titration to phenolphthalein and methyl orange endpoints are given in the Appendix.

1.3.3.1 Method of reporting

Express as ppm OH, HCO_3, or CO_3 ions.

1.4 Total hardness

Many authors appear to consider hardness and total alkalinity as the same. This is because when both are expressed as $CaCO_3$, the two values may be approximately equal.

However, hardness is principally the total of soluble Ca and Mg salts present in the water, expressed as its $CaCO_3$ equivalent. Included in hardness is that calcium present as $CaCl_2$ or $CaSO_4$; this will not appear in alkalinity since these salts are not titratable with HCl. Waters contaminated with ocean salts or from dry land areas may have quite appreciable amounts of Ca and Mg in these forms. The calcium sulphates and chlorides, while available in water for plant and animal assimilation, do not serve as effective buffers for storage of CO_2, where tension of this gas increases during the night as the result of respiration and decomposition.

1.4.1 Chemical analysis

The analysis for hardness should be made using the sodium salt of ethylene diamine tetraacetic acid (EDTA) with chrome black T or calmagite as the indicator. The endpoint comes when the colour changes from wine-red to blue. Methods of analysis are given in the Appendix.

1.4.2 Method of reporting

Express total hardness as ppm $CaCO_3$ equivalent.

1.4.3 Interpretation

Total hardness is used to classify waters as "hard" or "soft" but the amount of hardness listed as "hard waters" varies with different authors. It is suggested that the definition of hard and soft waters be as follows:

Soft waters - those with total hardness less than 50 ppm $CaCO_3$ equivalent.

Hard waters - those with total hardness of 50 ppm or more $CaCO_3$ equivalent.

In pond fish culture, waters with hardness of 15 ppm or more are satisfactory and do not require addition of lime. Waters with hardness less than 12 ppm usually require liming both of waters and bottom soils before high production can be obtained. Waters with hardness less than 5 ppm $CaCO_3$ equivalent cause slow growth, distress and eventual death of fish.

1.5 Calcium

Total hardness is principally soluble salts of calcium and magnesium. Usually the amount of calcium is two or more times that of magnesium.

1.5.1 Chemical analysis

Calcium may be differentiated by EDTA titration with murexide (ammonium purpurate) as indicator. The endpoint is an orchid-purple colour. This method is given in the Appendix.

1.5.2 Flame photometer

Calcium in solution may be atomized in a flame photometer where it gives an orange colour, whose intensity is proportional to the amount of calcium. This is a rapid method, but the titration methods above appears somewhat more accurate.

1.5.3 Reporting results

Report as ppm $CaCO_3$ equivalent. Since calcium carbonate is soluble only up to 15 ppm in pond waters, higher results would indicate calcium to be present as bicarbonate, or combined with a stronger acid.

1.6 Hydrogen ion concentration (pH)

The pH of pond water goes through a diurnal change, being most alkaline in mid-afternoon and most acid just before daybreak because of the combined effects of respiration, decay and photosynthesis. For description of a water, either the pH just before daybreak or the diurnal change should be reported. A soft water may have a pH of 6.5 just before daybreak changing gradually to 9.5 or higher by mid-afternoon.

There is only one accurate method of determining pH - the electrometric glass electrode. Papers and colorimetric methods give quite inaccurate results, varying from the true value by a few tenths to 2 or 3 pH units. Readings should be made as rapidly as possible after the sample is taken. The pH meter should be calibrated against a known pH solution that is within 2 pH units of the values being determined. This is not as important with better laboratory models, but is absolutely essential for portable field meters.

2 ANALYSES OF BOTTOM SOILS

2.1 Collection of samples

This is most easily done while the pond is dry, but samples can be taken with Peterson or Eckman dredges or other bottom samplers while the ponds are full. Samples should be taken in a number of locations (4 to 6 per pond) poured together and thoroughly mixed. A composite sample of 1 litre of soil may then be taken for analyses.

2.2 Preparation of soils for analyses

Pond bottom soils should be dried at approximately 40°C. Drying may be in an oven or under an infrared lamp. To facilitate grinding, stir soils while drying to break them into small pieces. After drying for 48 to 72 hours, grind in a mortar and pass through a 20-mesh screen.

2.3 pH of soils

A 20-gram sample of the dried soil is mixed with 20 ml water and after 1 hour the pH determined with a glass electrode pH meter. Detailed directions are given in the Appendix.

2.3.1 Interpretation

Soils with pH of 5.5 and higher seldom give higher fish production following liming. However, with a pH of 4.5 or less, good production is impossible without liming.

2.4 Lime requirements of pond soils

A buffer solution of known pH (7.0) is mixed with the wet soil sample used for pH determination or prepared freshly in the same manner. After stirring for one hour, the decrease in pH is recorded. Each 0.1 reduction in pH indicates need for approximately 500 kg calcium carbonate (ground limestone) per hectare.

The detailed method is given in the Appendix.

It is unnecessary to run this analysis unless the pH of the soil is below 5.0.

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4 APPENDIX

1 ANALYSES OF WATERS

1.1 Dissolved oxygen

1.1.1 Winkler method for determination of dissolved oxygen (DO)

This method of oxygen analysis determines the free dissolved O_2 in water. It is based on the following reactions:

(i) $MnSO_4 + 2\ NaOH \longrightarrow Mn(OH)_2 + Na_2SO_4$

(ii) $Mn(OH)_2 + O \longrightarrow H_2MnO_3$ (brown precipitate)

(iii) $H_2MnO_3 + 2\ H_2SO_4 + 2\ KI \longrightarrow MnSO_4 + 3\ HOH + K_2SO_4 + I_2$

The released I_2 gives the solution a yellow to brownish colour, and the intensity of the colour is proportional to the O_2 content of the original water sample. The amount of I_2 is determined by titration with sodium thiosulphate:

(iv) $I_2 + 2\ Na_2S_2O_3 \longrightarrow Na_2S_4O_6 + 2\ NaI$

The end point is determined by the use of starch indicator, which gives a blue colour with free I_2 and no colour with NaI. The disappearance of the blue colour marks the end of the reaction.

If the titrated solution is allowed to stand for several minutes, subsequently the blue colour returns due to absorption of additional O_2 from the air and the release of I_2 from the HI present in the acid solution:

(v) $4\ HI + O_2 \longrightarrow 2\ I_2 + 2\ H_2O$

Also, presence of Fe (ic) or NO_2 may cause subsequent release of free I_2 from KI or NaI. Consequently, the sample should not be again titrated after the original end point has been released.

1.1.2 Modifications of the Winkler method

For exceptional waters containing considerable amounts of ferrous iron, the Rideal-Stewart modification of the Winkler Method may be used. This involves oxidation of the ferrous iron to ferric iron with potassium permanganate.

For most waters, nitrite (NO_2-) is the principal interfering salt. Sulphamic acid pretreatment reduces the error from this interference:

$$NH_2SO_2OH + HNO_2 \longrightarrow H_2SO_4 + N_2\ \ H_2O$$

Since the sulphamic acid is stable in sulphuric acid and easy to use, this modification is used in all waters containing fish.

Sodium azide (NaN_3) may also be used to eliminate interference by nitrites:

$$NaN_3 + H_2SO_4 + HNO_2 \longrightarrow N_2 + H_2O + NaHSO_4$$

This method is not given although it is equally as effective as the sulphamic acid modification.

The iodine difference method of Ohle may be used in special cases, where great accuracy is desired. This corrects both for the presence of materials causing high results by releasing iodine from KI and those causing low results by absorption of free iodine.

Reagents

For Rideal-Stewart modification

(i) Potassium permanganate solution: Dissolve 3.16 g potassium permanganate in distilled water and dilute to 500 ml. Transfer to a clean brown bottle and keep in the dark.

(ii) Potassium oxalate solution: Dissolve 10 g of potassium oxalate in water and dilute to 500 ml.

For sulphamic acid pretreatment of water

(iii) Sulphamic acid solution: Add 20 ml concentrated sulphuric acid to 80 ml water. Add 4 g sulphamic acid and shake until dissolved. Store in brown bottle with glass stopper.

For standard Winkler method

(iv) Manganous sulphate solution: Dissolve 240 g of manganous sulphate in water and dilute to 500 ml.

(v) Alkaline potassium iodide solution: Dissolve 250 g of sodium hydroxide and 75 g of potassium iodide in water and dilute to 500 ml. Use a flask with a rubber stopper for storage.

(vi) Standard 0.025 N sodium thiosulphate solution: In reaction (iv) above, 2 molecules of sodium thiosulphate react with 2 iodide equivalents. Therefore, an N/1 solution of sodium thiosulphate contains the molecular weight of this compound in grams per litre of solution. The salt used is $Na_2S_2O_3 \cdot 5H_2O$, with a molecular weight of 248.19. A 0.025 N solution then contains:

$$248.19 \times 0.025 = 6.2048 \text{ g per litre of solution.}$$

Weigh out accurately 6.205 g of chemically pure recrystallized sodium thiosulphate. Place in a 1-litre, glass stoppered volumetric flask and dilute to 1 litre with freshly boiled and cooled distilled water. Add several drops chloroform as a preservative, label, and stopper tightly. Keep this reagent in the dark.

Each ml of 0.025 N sodium thiosulphate is equivalent to 0.2 mg of oxygen or to 0.1400 ml of oxygen at 0°C and 760 mm pressure.

As this reagent is not permanent, it should be restandardized at 30-day intervals against a 0.025 N solution of potassium dichromate.

(vii) Standard 0.025 N Potassium dichromate solution: This salt makes a permanent standard and should be prepared carefully. It reacts with KI in acid solution to liberate a definite amount of I_2 as follows:

$$6\ KI + K_2Cr_2O_7 + 14\ HCl \rightarrow 8\ KCl + 2CrCl_3 + 7\ H_2O + 3\ I_2$$

The liberated iodine is then titrated with the thiosulphate solution.

Since in the above reaction one molecule of $K_2Cr_2O_7$ reacts with 6 iodine equivalents, a normal solution of potassium dichromate equals the molecular weight in grams divided by 6. The $K_2Cr_2O_7$ contains no water of crystallization and has a molecular weight of 294.2; a 0.025 N solution of this salt then contains:

$$\frac{294.2}{6} \times 0.025 = 1.2258 \text{ g per litre.}$$

Weigh accurately 0.6129 g of pure crystalline $K_2Cr_2O_7$ and dilute to 500 ml in a glass stoppered volumetric flask with freshly boiled and cooled distilled water.

(viii) 25% potassium iodide solution: Dissolve 25 g KI in 100 ml freshly boiled and cooled distilled water.

(ix) Starch indicator: Add 2 g soluble starch to 100 ml water. Heat until transparent. Add 0.5 ml formalin for preservative.

Or use: Modified starch glycerite:

a. Add 3 g powdered soluble starch to 100 ml glycerin.

b. Heat to 190°C.

c. Cool to room temperature. If solution gels with age, reheat to 190° and add glycerin.

Starch indicator is stable for about 30 days, while the modified starch glycerite keeps indefinitely.

Standardization of approximately 0.025 N sodium thiosulphate

(i) Place in a beaker 100 ml of freshly boiled and cooled distilled water.

(ii) Add 3 ml of a 25% solution of KI.

(iii) Add from a burette 50 ml of the standard 0.025 N potassium dichromate.

(iv) Add 10 ml concentrated HCl.

(v) Titrate the liberated I_2 with the standard 0.025 N sodium thiosulphate solution. When the yellow colour has almost disappeared, add about 2 ml starch indicator and continue the titration until the blue colour just disappears. The final colour may be a light green due to chromic salts.

(vi) The factor for the 0.025 N thiosulphate equals:

$$\frac{\text{ml standard dichromate}}{\text{ml standard thiosulphate}} = \frac{50}{X}$$

For example, if the titration requires 48.8 ml of approximately 0.025 N thiosulphate, the factor $= \frac{50}{48.8} = 1.024$

1.1.3 Collection of sample

Collect the sample in a narrow-necked glass-stoppered bottle of 250-300 ml capacity (standard B O D bottle) by means of an apparatus designed to avoid the entrapment or absorption of any oxygen from the atmosphere. Note the temperature.

1.1.4 Determination of dissolved oxygen

Removal of ferrous iron and nitrites: Follow modification I only if iron or other interfering materials prevent the use of modification II.

(i) Rideal-Stewart modification

(a) Remove the stopper from the bottle and add 0.7 ml of concentrated sulphuric acid and then 1 ml of the potassium permanganate solution. Introduce these and all other reagents by pipette under the surface of the liquid. Insert the stopper and mix by inverting the bottle several times.

b. If a noticeable excess of potassium permanganate is not present after 5 minutes, again add 1 ml of the permanganate solution; if this is still insufficient, use a stronger permanganate solution, but avoid a large excess.

c. After 20 minutes destroy the excess permanganate by adding 1 ml of the potassium oxalate solution, re-stopper the bottle at once, and mix its contents. Let stand several minutes. If the pink colour persists, add an additional 1 ml of potassium oxalate, re-stopper, and mix. Repeat until solution is free of pink colour, but avoid adding excess oxalate as this causes low results. (Continue with standard Winkler method).

For removal of interference by nitrites use the following method:

(ii) Sulphamic acid modification

Use this modification for most pond waters.

Remove the stopper and add 1 ml of the sulphamic acid solution. Replace stopper and mix by inverting bottle. After 30 seconds, continue with the standard Winkler method of analysis.

(iii) Standard Winkler method

(a) Add 1 ml of the manganous sulphate solution and 3 ml of the alkaline potassium iodide solution. Mix by rapid inversion for 30 seconds. Allow the precipitate to settle. Reshake and allow to settle. (For sea water, alternately shake and allow to settle for a 10-minute period.)

(b) Add 1 ml of concentrated sulphuric acid and mix by shaking. If water is high in iron or organic matter, continue promptly with steps (c) and (d).

(c) Measure 200 ml of the contents of the bottle into a graduated cylinder. Discard the remainder of the sample and carefully pour the measured sample back into the sample bottle or into an Erlenmeyer flask with the minimum of aeration.

(d) Titrate with 0.025 N thiosulphate until the sample becomes a faint yellow. Add about 2 ml of the starch indicator and continue the titration until the blue colour disappears.

(e) Report results as parts per million. Each ml of standard 0.025 N sodium thiosulphate equals 1 ppm DO. For example, if the titration required 4.5 ml of 0.025 N thiosulphate, the sample contained 4.5 ppm DO.

If the thiosulphate had a factor of 1.024, each ml = 1.024 ppm O_2 and the above sample contained:

$$4.5 \times 1.024 = 4.6 \text{ ppm DO}$$

Modified Winkler method for dissolved oxygen determination by the iodine difference method (Ohle 1953)

Reagents

(i) Iodine stock solution

Dissolve 5 g I_2 plus 100 KI in 114 ml water. 1 ml of this solution contains about 44 mg I_2 and 0.88 g KI.

(ii) Iodine reagent

Dissolve 35 g NaCl in 100 ml distilled water; add 10 ml of the above iodine stock solution. 1 ml contains about 4 mg I_2 and 80 mg KI.

(iii) Alkaline - KI

Dissolve 100 g NaOH in 200 ml boiled distilled water; add 50 g KI and shake till dissolved.

(iv) Manganous sulphate

Dissolve 100 g Mn $SO_4 \cdot 4H_2O$ in 200 ml distilled water and filter.

(v) Concentrated H_2SO_4

This is more satisfactory than the sodium bisulphite recommended by Ohle.

(vi) Starch solution

Boil 1 g soluble starch in 100 ml distilled water; cool, add 0.5 ml formalin.

(vii) Sodium thiosulphate

Dissolve 6.2048 g $Na_2S_2O_3 \cdot 5H_2O$ in a volumetric 1-litre flask; add 1 ml 20% NaOH plus 10 ml isobutyl alcohol and dilute to 1 litre.

Procedure for iodine-difference method

(a) Collect water for oxygen sample to prevent contamination in air. Use standard BOD bottle (300 ml).

(b) Add 2 ml of iodine reagent. If this free iodine should disappear, add an additional 2 ml. Add the above to each of 2 water samples taken from the same depth or source of water. Cover, or keep out of light. The duration of I_2 treatment should be the same for each bottle of the pair.

(c) To one of the above bottles, add:

1 ml $MnSO_4$

3 ml alkaline-KI

Stopper and shake briskly for 10 to 15 seconds. Then add 1.5 ml concentrated H_2SO_4 before the precipitate begins to settle. Let stand 10 minutes. Titrate 200 ml with 0.025 N thiosulphate, using starch indicator near the end point.

(d) To the other bottle of the pair, add

3 ml alkaline-KI

Stopper, shake for 10-15 seconds. Add 1.5 ml concentrated H_2SO_4 before the precipitate settles. Let stand 10 minutes. Titrate 200 ml with thiosulphate as above.

(e) The difference in titre is equivalent to the dissolved oxygen plus that added in the reagents.

The iodine equivalent to dissolved oxygen is liberated in the first bottle only. The titre for the second bottle corrects for interfering substances liberating and/or absorbing iodine if the reaction time for the two is the same.

(f) For most accurate determination of O_2, the proportionate volumes of reagents must be subtracted from the volume titrated and the dissolved oxygen in the reagents must be subtracted from the results of the titration. Correction for volumes of reagents can be obtained by titrating 208 ml instead of 200 ml.

1.2 Acidity and alkalinity of water

1.2.1. Determination of free CO_2, and HCO_3, CO_3 and OH alkalinities

The titration method is described here for these determinations. The approximate relationships of CO_2 - and HCO_3^-, CO_3^{--}, and OH^- alkalinities are shown on the accompanying chart.

Separation of the various forms of CO_2 is based on the fact that the end point of phenolphthalein (approximately 8.3), gives a satisfactory division between carbonates and bicarbonates. In more alkaline waters from pH 8.4 to 10.5, there may be a mixture of HCO_3^- and CO_3^{--} but the bicarbonate decreases sharply as the pH value approaches 10.4. At higher pH values relatively insignificant amounts of bicarbonate are present. In waters more acid than 8.3, practically no carbonate is present, but only varying mixtures of HCO_3 - and CO_2.

In waters more acid than pH 4.0, acidity is due to stronger acids than CO_2. Actually, at atmospheric pressures CO_2 cannot make water more acid than pH 5.0. Titration with Na_2CO_3 or NaOH to the phenolphthalein end point allows estimation of the free CO_2 present in the water.

Principles

(i) Water sample acid to phenolphthalein and alkaline to methyl orange

Contains free CO_2 and bicarbonates

(a) Determine free CO_2 by titration with Na_2CO_3 with phenolphthalein indicator.

$$CO_2 + HOH + Na_2CO_3 \longrightarrow 2\ NaHCO_3$$

The equivalent weight of Na_2CO_3 in this reaction is the molecular weight divided by two.

(b) Determine the HCO_3- in a fresh sample by titration with HCl with methyl orange indicator.

$$HCl + NaHCO_3 \longrightarrow NaCl + HOH + CO_2$$

(ii) Water sample alkaline to phenolphthalein (pink colour)

Contains CO_3^{--}, HCO_3^- or possibly OH^-

(a) Determine phenolphthalein alkalinity by titration with standard HCl to phenophthalein end point ($pH = 8.3$).

$$Na_2CO_3 + HCl \longrightarrow NaHCO_3 + NaCl$$

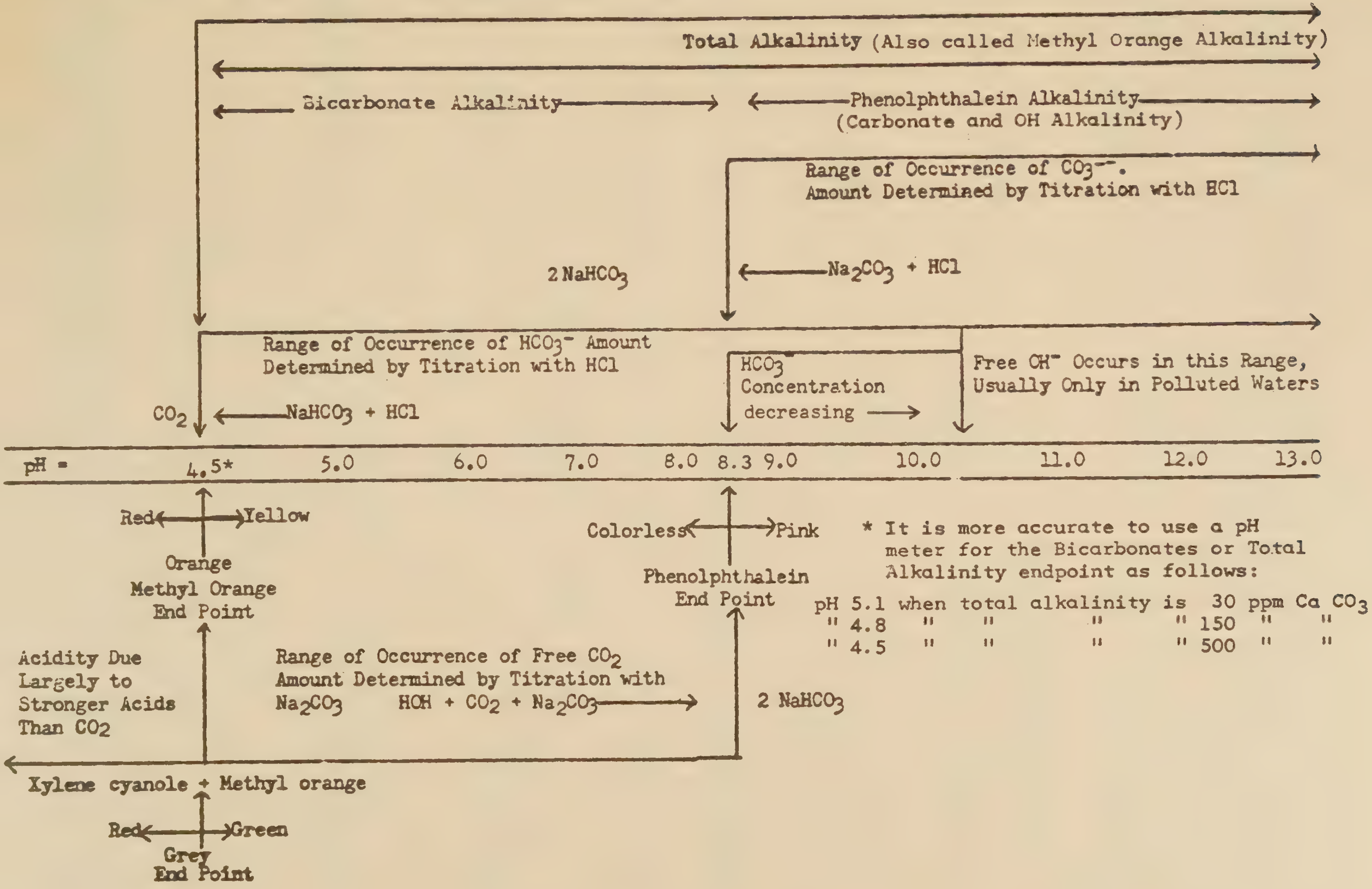
The equivalent weight of Na_2CO_3 is the molecular weight, since 1 molecule combines with 1 equivalent of HCl.

(b) Using the colourless solution from the above titration, determine the methyl orange alkalinity by titration with standard acid to the methyl orange or the methyl orange-xylene cyanole end point (pH 4.5).

$$NaHCO_3 + HCl \longrightarrow NaCl + HOH + CO_2$$

This bicarbonate is a mixture of the bicarbonate originally present and that formed in the preceding titration from the carbonate, if present. The latter will require the same volume of acid as was used in the original titration under Section a. If this amount is subtracted from the volume used in the second titration, the difference is that required by the bicarbonate originally present.

Fig. 1 RELATIONSHIP AND DETERMINATION OF CO_2, HCO_3^-, CO_3^{--}, AND OH^- IN NATURAL WATERS


Total Alkalinity (Also called Methyl Orange Alkalinity)
Bicarbonate Alkalinity
Phenolphthalein Alkalinity
(Carbonate and OH Alkalinity)
Range of Occurrence of CO3--.
Amount Determined by Titration with HCl
2 NaHCO3
Na2CO3 + HCl
Range of Occurrence of HCO3- Amount
Determined by Titration with HCl
HCO3
Concentration
decreasing
Free OH- Occurs in this Range,
Usually Only in Polluted Waters
CO2
NaHCO3 + HCl
pH =
4.5*
5.0
6.0
7.0
8.0
8.3
9.0
10.0
11.0
12.0
13.0
Red
Yellow
Orange
Methyl Orange
End Point
Colorless
Pink
Phenolphthalein
End Point
Acidity Due
Largely to
Stronger Acids
Than CO2
Range of Occurrence of Free CO2
Amount Determined by Titration with
Na2CO3
HOH + CO2 + Na2CO3
2 NaHCO3
Xylene cyanole + Methyl orange
Red
Green
Grey
End Point

* It is more accurate to use a pH meter for the Bicarbonates or Total Alkalinity endpoint as follows:

pH 5.1 when total alkalinity is 30 ppm Ca CO_3
" 4.8 " " " " 150 " "
" 4.5 " " " " 500 " "

Interpretation

(a) Total alkalinity is because of hydroxide (OH^-) if sample has phenolphthalein alkalinity but no methyl orange alkalinity (no HCO_3^-), because titration of carbonate to the phenolphthalein end point would have produced bicarbonate.

(b) Total alkalinity is due to only HCO_3^- if there is bicarbonate alkalinity but no phenolphthalein alkalinity.

(c) Total alkalinity is due to only CO_3^{--} if the bicarbonate alkalinity equals the phenolphthalein alkalinity.

Reagents

(a) Standard 0.045 N Na_2CO_3 solution

The molecular weight of sodium carbonate is 106, and since it contains 2 equivalents, a 1.0 N solution contains $\frac{106.0}{2} = 53.0$ g per litre.

Preparation of stock standard solution of Na_2CO_3:

(i) Heat a clean 100 ml evaporating dish to 200°C in an oven for 30 minutes. (Or heat at 120°C for 10 hours). Cool in a desciccator. Remove and weigh accurately.

(ii) Add approximately 30 g of CP reagent-grade Na_2CO_3.

(iii) Heat to 200°C in an oven for 30 minutes. Stir and reheat for 30 minutes. Cool in a desciccator. Remove, weigh accurately.

(iv) Dissolve in freshly boiled and cooled distilled water; transfer to a 500 ml volumetric flask and dilute to the mark with the boiled and cooled distilled water.

(v) Calculate the actual normality of this stock solution as follows:

$$N = \frac{\text{Weight in grams of } Na_2CO_3 \text{ per litre}}{53.0}$$

For example, if the weight in Section 3 was 58.431 g Na_2CO_3 per litre, the stock solution was:

$$N = \frac{58.431}{53.0} = 1.025N$$

Preparation of 0.0454N Na_2CO_3 from the stock solution:

(vi) The ml of stock standard solution required to make 1 litre of 0.0454N Na_2CO_3 is calculated as follows:

$$\frac{0.0454\ N}{\text{Normality of stock solution}} \times 1000$$

For example, if the stock solution was 1.025 N Na_2CO_3, then

$$\frac{0.0454}{1.025} \times 1000 = 44.3 \text{ ml of } 1.025\ N\ Na_2CO_3$$

required to make 1 litre of 0.0454N Na_2CO_3.

(vii) Measure accurately the required ml of the stock solution from a burette into a 1-litre volumetric flask. Dilute to the mark with freshly boiled and cooled distilled water. Stopper tightly with a rubber stopper.

(b) Standard 0.016 N HCl

This standard is most accurately prepared from a constant boiling mixture as follows:

Stock solution of standard HCl

(i) Place 100 ml pure concentrated HCl and 400 ml distilled water in a beaker.

(ii) Boil until half the solution has evaporated.

(iii) Record the barometric pressure during boiling.

(iv) The remaining solution from (ii) will have a constant composition as indicated in the following table:

Barometric pressure	% HCl in solution	Grams solution required for 1 litre 1.0 N HCl
770	20.197	180.407
760	20.221	180.193
750	20.245	179.979
740	20.269	179.766
730	20.293	179.555

Values for intermediate barometric pressures are determined by interpolation.

(v) Weigh accurately and rapidly approximately 190 ml of the acid solution and place in a glass-stoppered volumetric flask. Dilute to 1 litre with recently boiled and cooled distilled water.

(vi) Determine the normality of the above stock standard solution as follows:

$$\frac{\text{Actual weight HCl solution}}{\text{Grams solution required for 1 N HCl (From Table Step (iv))}}$$

For example, if the barometric pressure during boiling was 740 (Step (iii)), then 179.766 g of the solution was required to make 1 litre of 1.0 N HCl (Step (iv)). If the actual weight of the acid solution was 195.120 (Step (v)), then the normality of the stock solution was:

$$\frac{195.120}{179.766} = 1.085 \text{ N}$$

Preparation of 0.0163N HCl from the standard stock solution:

(vii) The ml of standard stock solution required to make 1 litre of 0.0163 N HCl is calculated as follows:

$$\frac{0.0163}{\text{Normality of stock solution}} \times 1000$$

For example, if the stock solution is 1.085 N HCl, then,

$$\frac{0.0163}{1.085} \times 1000 = 15.0 \text{ ml of } 1.085 \text{ N HCl}$$

is required to make 1 litre 0.0163 N HCl.

(viii) Measure accurately from a burette the required number of ml of the standard stock solution into 1-litre volumetric flask with a ground glass stopper. Dilute to the mark with freshly boiled and cooled distilled water.

(c) Either of the following indicators may be used.

Methyl orange

Dissolve approximately 0.05 g methyl orange in 25 ml water. This indicator has its end point at pH = 4.5, and at this point has an orange colour. In a more acid range it is red and in a more alkaline range, it is yellow. The end point is difficult to detect.

Methyl orange - Xylene cyanole

Dissolve 0.2 g methyl orange plus 0.2 g xylene cyanole in 100 ml distilled water. Its end point is a grey colour at pH 4.5. In more alkaline waters it is green and in more acid waters, it is red. The end point is easy to detect.

(d) Phenolphthalein

Dissolve approximately 0.05 g phenolphthalein in 25 ml of 50% alcohol. This indicator gives a pale pink colour at pH = 8.3, its transition point. In more acid solutions it is colourless and in more alkaline solutions it is red.

Procedures

Free carbon dioxide

Pretest two small water samples of approximately 20 ml by adding several drops of methyl orange to one and several drops phenolphthalein to the other. If the sample is acid (red) to methyl orange, acidity is due to acids stronger than CO_2. If the samples are alkaline (yellow) to methyl orange and acid (colourless) to phenolphthalein, the acidity is assumed to be due to carbon dioxide.

(i) In the latter case, carefully pipette 200 ml of the water sample into an Erlenmeyer flask.

(ii) Add 10 drops phenolphthalein. (The solution should remain colourless).

(iii) Titrate to a faint pink (approximately pH 8.3) with 0.0454N sodium carbonate.

(iv) The number of ml of 0.0454N sodium carbonate X 5 = ppm free CO_2.

1.2.2 Alkalinity

CO_3^{--}, HCO_3^{-}, and OH^{-} determination

(i) Determination of phenolphthalein alkalinity

(a) To 100 ml of the sample water, add a few drops of phenolphthalein.

(b) If the solution remains colourless, no phenolphthalein alkalinity is present. Continue with Section 2-a.

(c) If a pink colour develops upon the addition of phenolphthalein, titrate with 0.0163N HCl, adding a drop every 2 to 3 seconds until the pink colour disappears. Record the burette reading as phenolphthalein alkalinity (P).

(d) Save the sample for titration under Section ii-b

(ii) Determination of bicarbonate alkalinity

(a.) To the water sample from (i)-b above, add several drops methyl orange or methyl orange-xylene cyanole and titrate with 0.0163 N HCl to the end point (orange colour, or grey colour respectively). Multiply burette reading by 10.1 to obtain the value of HCO_3^- (bicarbonate ion) in ppm.

(b) To the water sample from (i)-c above, add several drops of methyl orange or methyl orange-xylene cyanole indicator and titrate with 0.0163 N HCl to the end point. Record burette reading as bicarbonate alkalinity (B).

If the titre is large, it is best to titrate to the end point, then boil to expel CO_2 and retitrate to the end point. The presence of large amounts of CO_2 may give a premature end point if this is not done.

Calculations

(a) If B = 0.0 ml, P represents OH^- alkalinity.
Multiply ml of 0.045N HCl required under (i)-c by 18 to obtain OH^- alkalinity as ppm NaOH, or multiply by 22.5 to express OH^- alkalinity as its equivalent in ppm $CaCO_3$.

(b) If B ml - P ml = 0, then there is no bicarbonate (HCO_3^-) alkalinity, but only CO_3^{--} alkalinity. Multiply P ml by the factor 10 to obtain the concentration of CO_3^{--} as ppm in water sample.

(c) If B ml - P ml = X ml, then

(i) Multiply P ml by 10 to obtain the concentration of CO_3^{--} ions as ppm in the water sample.

(ii) Multiply X ml by 10.1 to obtain the concentration of HCO_3^{--} ions as ppm in the same sample.

1.3 Total hardness (Diehl, Goetz and Hach Method)

Hardness of water is due principally to soluble salts of calcium and magnesium. Temporary hardness is due to calcium and magnesium bicarbonates. This is called " temporary " because upon boiling, the bicarbonates change to carbonates and calcium and magnesium are precipitated in part.1.

$$Ca(HCO_3)_2 \longrightarrow CaCO_3 + H_2O + CO_2\uparrow$$

Permanent hardness is due principally to soluble Ca and Mg carbonates and salts of inorganic acids (eg. $CaSO_4$)[1]. Permanent plus temporary hardness = total hardness.

The following method for total hardness is much less time-consuming than the older methods.

Principle: The indicator, Chrome black T forms a wine-red colour with Mg ions. The sodium salt of ethylenediamine - tetraacetic acid (sometimes called versene) is the standard solution used for titration. It combines first with free Ca ions, next with free Mg ions and, finally, at the end point extracts Mg from the Mg - chrome compound, thus changing the colour from wine-red to blue.

The blue end point occurs at pH 7.0 - 10 and a buffer solution must be used which keeps the pH at approximately 9 - 10. This is necessary because the indicator has two colour changes:

$$\text{wine-red} \underset{\text{pH } 6.3}{\rightleftarrows} \text{blue} \underset{\text{pH } 11.5}{\rightleftarrows} \text{orange}$$

---

[1] Solubility at 25°C is: $CaCO_3$ - 14 ppm; $MgCO_3$ - 106 ppm; $CaSO_4$ - 300 ppm.

Reagents

These reagents can be purchased ready to use, or made as follows:

Buffer: Mix 67.5 NH_4Cl with 570 ml concentrated NH_4OH. Dilute to 1 litre.

Indicator: Mix 0.5 g chrome black T (known also as Eriochrome black T and as F 241) with 4.5 g of hydroxylamine hydrochloride; dissolve 5 g of this mixture in 100 ml alcohol (70%).

Standard $CaCl_2$: Dissolve 1.000 g pure $CaCO_3$ in diluted HCl (1-10) and dilute to exactly 1 litre and store in a glass-stoppered bottle. 1 ml = 1.0 mg $CaCO_3$.

Standard sodium ethylenediamine tetraacetate (EDTA): Dissolve 4.0 g disodium dihydrogen ethylenediamine tetraacetate (also known as disodium dihydrogen versenate) and 0.1 g $MgCl_2 \cdot 6H_2O$ in 750 ml distilled water and dilute to 1 litre in a pyrex volumetric flask.

Standardize by titrating against 25 ml of standard $CaCl_2$ solution plus 1 ml of buffer plus 4 drops indicator. Dilute so that 1 ml of standard = 1.0 mg $CaCO_3$.

Procedure

(a) Pipette 50 ml water sample into a 250 ml Erlenmeyer flask.

(b) Add 1 ml buffer and mix.

(c) Add 4 drops indicator.

(d) Titrate with above standard solution. At this end point, the solution should be clear and should change from wine-red to pure blue.

(e) Multiply ml standard used x 20 = total hardness as ppm $CaCO_3$.

(f) For very soft waters, 200 ml sample may be titrated and the ml of standard required multiplied by 5 to obtain ppm $CaCO_3$.

1.4 Calcium in pond waters

Reagents

1.0 N NaOH: Weigh approximately 40 g pure NaOH and dilute to 1 litre with freshly boiled and cooled distilled water.

Calcium indicator: Mix 0.2 g Murexide (also called NH_4 purpurate) with 100 g NaCl. Grind to a uniform mix with a mortar and pestle.

Standard sodium ethylenediamine tetraacetate (See total hardness)

Procedure

(a) Measure 50 ml water into a 250 ml Erlenmeyer flask or into a casserole.

(b) Add 2 ml of 1.0 N NaOH and stir.

(c) Add 0.2 g calcium indicator and stir. (If Ca is present, colour is salmon pink).

(d) Titrate with standard sodium ethylenediamine tetraacetate, stirring constantly. Towards the end point, the colour has a purple tinge. At the end point the colour is orchid-purple.

(e) Multiply ml standard required x 20 = Ca (as ppm $CaCO_3$).

1.5 Magnesium in pond waters

Total hardness (as ppm $CaCO_3$) - Ca (as ppm $CaCO_3$) = Mg (as ppm $CaCO_3$).

Mg (as ppm $CaCO_3$) x 0.84253 = Mg (as ppm $MgCO_3$).

This is an estimate as "hardness" may include very small amounts of other salts in addition to calcium and magnesium.

1.6 Hydrogen ion concentration

There is only one satisfactory method of determining the pH of pond waters and that is by the use of the electrometric glass electrode. Laboratory and portable models are available.

Universal indicator dyes are available which give different colours over the entire range of pH. The colour produced is then compared to a colour chart. Errors in determining pH by this method in natural waters vary from 1.0 to 3.0.

Colorimetric determinations using pH indicators, with solutions of known pH for comparison are more accurate, but certain waters may give colours varying much from the true pH value.

Overlapping indicators, as shown on the following page, may be used for approximation of the true pH, but are subject to errors of the type mentioned above.

Indicator papers are inaccurate, expecially in poorly buffered waters. They are useful only to obtain approximate pH values.

For purposes of water classification, the pH of waters should be taken preferably just before daybreak, or before active photosynthesis has materially reduced the available free and/or half-bound carbon dioxide.

2 BOTTOM SOILS

2.1 Preparation of soil for analyses

Pond bottom soils to be analyzed for calcium, magnesium, inorganic phosphorus, pH, and organic matter are dried at a temperature of approximately 40°C. Drying may be done inside an oven or under an infrared lamp. To facilitate grinding, soils should be broken up into small pieces as they dry, but while still moist and soft. After drying, grind soils in a mortar and sieve through a 20-mesh screen. It takes 2 to 3 days to dry 500 ml of soil sample in a suitable-sized bowl.

2.2 Determination of soil pH

Shake 20 g of soil sample with 20 ml distilled water for 5 minutes. Let stand 30 minutes to 1 hour. Measure pH by means of a glass electrode pH meter. While the electrodes are immersed in the mixture, swirl the mixture by rotating the container or use a mechanical stirrer. Allow 30 seconds or so for the needle to stop drifting and read while stirring.

This sample may be saved for determination of the lime requirement.

OVERLAPPING INDICATORS

Their pH at colour changes in pond waters

Thymol blue

Red	Orange Yellow
1.8	2.4

Brom phenol blue

Yellow	Purple
3.4	3.8

Methyl red

Red	Yellow
4.8	6.0

Brom cresol purple

Yellow	Purple
5.4	6.4

Brom thymol blue

Yellow	Green	Blue
5.4	6.4	7.0

Phenol red

Yellow	Pink
6.8	7.4

Cresol red

Yellow	Purple
7.0	8.2

Phenolphthalein

Colourless	Pink
8.0	9.0

Thymol blue

Yellow-green	Blue
8.4	9.0

Thymolphthalein

colourless	Blue
9.0	10.5

2.3 Lime requirements of soils

Reagents: Buffer solution (pH 7.0)

(a) Dissolve 8 g p-nitrophenol in 100 ml hot distilled water (60°-70°C).

(b) Dissolve 40 g calcium acetate in 50 ml warm distilled water.

(c) Mix a and b in a 1-litre beaker.

(d) Make a paste of 0.62 g MgO with distilled water and add to the above mixture. Wash down with hot distilled water. Mix thoroughly and allow to cool.

(e) Dilute to approximately 1 litre with distilled water. Insert glass electrode and adjust to pH 7.00 with dilute HCl or MgO as required.

(f) Store in rubber-stoppered flask.

Procedure

(a) Add 20 ml buffer solution to soil sample on which pH was determined.

(b) Stir 2 to 3 times during a 1-hour period.

(c) Determine pH while stirring sample with mechanical stirrer.

(d) Each 0.1 reduction in pH indicates need for approximately 500 kg agricultural limestone ($CaCO_3$) per hectare.

****

VI/W-3

STANDARDIZATION OF BIOLOGICAL METHODS IN FISH CULTURE RESEARCH

by

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STANDARDIZATION OF BIOLOGICAL METHODS IN FISH CULTURE RESEARCH

Abstract

For population analysis, it is recommended that relationships be computed relating total length to weight, to maximum body depth, to maximum body width and to mouth width. Measurement of weight should be in grams and length, depth, and mouth width measurements in milli-metres.

It is further recommended that condition of fish be expressed as relative condition, calculated by dividing the observed weight of fish of a certain length by the standard average weight for this length, calculated from data supplied from all countries where this species is cultured.

It is recommended that for reporting populations and for construction of length-weight tables, the total length data be consolidated into cm-groups, using odd numbers to express the mid-point between 2 cm intervals. Thus the 5-cm group would be those fish whose total length varied from more than 4 cm up to and including 6 cm.

The need exists for a standard method of evaluating the yield and efficiency in food conversion of all fishes that are or appear to be useful in pond fish culture. It is recommended that this be done in a standard 120-day experimental period with a species at three levels of stocking in unfertilized ponds, in fertilized ponds and in ponds where fish are artificially fed. It is recommended that the fish stocked be in the 7-cm group, that fertilization be by superphosphate and that feeding be at the 3 percent level re-adjusted bi-weekly.

It is recommended that a list of accepted common names of fishes used in pond culture be compiled in the three official languages of FAO, namely English, French and Spanish.

Because of the rapid obsolescence of scientific names in the tilapias as well as other species, a need exists for a numbering system so that future readers of current literature may know the exact species used. It is suggested that the present scientific name be followed by coded numbers giving the continent, the country, the river system watershed and the date when first obtained from this habitat. Thus a fish Tilapia macrochir II 05021956 might indicate a fish from Africa (II), from Congo (05), in Ubangi River watershed (02), in the year 1956.

NORMALISATION DES METHODES BIOLOGIQUES EN MATIERE DE RECHERCHE PISCICOLE

Résumé

Pour l'analyse des populations, il est recommandé de calculer les relations en rapportant la longueur totale au poids, à la hauteur maximum du corps, à la largeur maximum et à la largeur de la bouche. Les mesures de poids doivent s'exprimer en grammes et celles de longueur, de hauteur et de largeur de la bouche, en millimètres.

Il est en outre recommandé d'exprimer la condition du poisson en termes de condition relative, c'est à dire qu'on divisera le poids observé des poissons d'une certaine longueur par le poids moyen standard pour cette même longueur, celui-ci étant calculé d'après les données fournies par tous les pays où cette espèce est élevée.

Pour la communication de renseignements relatifs aux populations et la préparation de tableaux longueur-poids, il est recommandé de récapituler les données concernant la longueur totale en utilisant des groupes centrimètriques, où les chiffres impairs exprimeront le point intermédiaire entre des intervalles de 2 cm. Ainsi, le groupe de 5-cm comprendrait des poissons dont la longueur totale est comprise entre plus de 4-cm et 6-cm.

Le besoin se fait sentir d'une méthode normalisée pour évaluer le rendement et le coefficient de conversion alimentaire de toutes les espèces qui sont ou qui paraissent utiles dans la pisciculture en étang. Il est recommandé de procéder à cette évaluation au cours d'une période expérimentale standard de 120 jours, en utilisant trois densités d'empoissonnement dans des étangs non fertilisés, dans des étangs fertilisés et dans des étangs où les poissons reçoivent une nourriture artificielle. Il est recommandé de procéder à cette expérience avec des poissons du groupe de 7-cm, d'effectuer une fumure au superphosphate et d'assurer une alimentation au niveau de 3 pour cent, réajustée deux fois par semaine.

Il est recommandé de préparer dans les trois langues officielles de la FAO (anglais, français et espagnol) une liste des noms vulgaires des poissons utilisés en pisciculture.

Etant donné les progrès rapides des connaissances, les noms scientifiques des tilapias et autres espèces sont rapidement dépassés; aussi, serait-il utile d'établir un système de numérotation de manière que les futurs lecteurs de la documentation actuelle sachent exactement quelle est l'espèce utilisée. Il est donc suggéré de faire suivre le nom scientifique actuel d'un code chiffré indiquant le continent, le pays et le système fluvial d'origine ainsi que la date à laquelle le premier prélèvement a été opéré. Ainsi, *Tilapia macrochir* II 05021956 pourrait désigner un poisson venant d'Afrique (II), du Congo (05), dans le bassin fluvial de l'Ubangi (02), en l'année 1956.

NORMALIZACION DE LOS METODOS BIOLOGICOS QUE SE APLICAN EN LAS INVESTIGACIONES DE PISCICULTURA

Extracto

Para el análisis de las poblaciones de peces, se recomienda que las relaciones se evalúen refiriendo la longitud total al peso, al grosor y anchura máximos del cuerpo, y a la anchura de la boca. La medida del peso debe expresarse en gramos y las de longitud, grosor y anchura de la boca en milímetros.

Se recomienda también que el estado del pez se exprese como un estado relativo, calculado mediante la división del peso observado en un pez de una longitud determinada por el peso medio normal para esta longitud, calculado según los datos proporcionados por todos los países en los que se cultiva la especie de que se trate.

Para la redacción de informes relativos a poblaciones y para la formación de cuadros de longitud y peso, se recomienda que los datos de longitud total se reúnan en grupos expresados por centímetros, utilizando números impares para expresar el punto medio existente entre intervalos de 2 centímetros. Así, el grupo de 5 cm correspondería a los peces cuya longitud total varíe desde más de 4 cm hasta 6 cm inclusive.

Hace falta un método normalizado de evaluación del rendimiento y de la eficacia de conversión de los alimentos respecto a todos los peces que sean, o parezca que hayan de ser, útiles en la piscicultura en estanques. Se recomienda que este método se aplique durante un período experimental uniforme de 120 días con una especie, en tres niveles

de repoblación, en estanques no fertilizados, en estanques fertilizados y en otros donde los peces sean alimentados artificialmente. Se recomienda que los peces con los que se ha relacionado la repoblación sean del grupo de 7 cm, que la fertilización se haga con superfosfato y que la alimentación se reajuste bisemanalmente en el nivel de 3 por ciento.

Se recomienda la formación de una lista de los nombres comunes de peces que han sido aceptados y se utilizan en piscicultura, en los tres idiomas oficiales de la FAO, a saber, inglés, francés y español.

Como los nombres científicos de la especie Tilapia y de otras especies caen rápidamente en desuso, es necesario adoptar un sistema de numeración, con objeto de que los lectores futuros de la literatura técnica corriente puedan conocer con exactitud la especie utilizada. Se sugiere que el nombre científico actual vaya seguido de números codificados que expresen el continente, el país, la cuenca hidrográfica y la fecha en la que se obtuvo por primera vez la especie en el habitat de que se trate. Así, un pez Tilapia macrochir II 05021056 podría indicar un pez de Africa (II), del Congo (05), de la cuenca del río Ubangi (02), del año 1956.

1 REPORTING COMPOSITION OF STANDING CROP OR PRODUCTION

In the American system of measurements, the composition of standing crops or production is expressed as the number and weight of each species by inch-groups. For example, total length of individual fish is reported as follows:

Up to and including 0.5 inch——fry

1-inch group = all fish from 0.5 inch up to and including 1.5 inches total length.

2-inch group = all fish from 1.5 inches up to and including 2.5 inches total length.

A similar grouping of total lengths is needed in the metric system for world-wide use: The following is suggested, using centimetre groups:

1 cm group = all fish up to and including 2.0 cm (size designated as fry).

3 cm group = all fish from 2.0 cm up to and including 4.0 cm total length.

5 cm group = all fish above 4.0 cm up to and including 6.0 cm.

7 cm group = all fish above 6.0 cm up to and including 8.0 cm.

Thus, for centimetre groups, the odd-numbers would be used to designate the mid-point between 2 cm differences in total length.

A population of *T. mossambica* would then be reported as follows:

Centimetre group	Number of fish	Total weight (kg)
1	43,560	4.356
3	10,500	5.250
5	4,350	13.050
7	2,160	19.300
9	35	0.525
11	100	3.180
13	1,260	51.660
15	666	41.960
Total	62,631	139.281

Length-weight tables for each species should then be computed for the above species and reported as follows:

Centimetre group	Average weight (g)
1	-
3	0.5
5	3.2
7	9.1
9	15.3
11	31.8
13	40.9
15	63.6
17	86.3
19	118.0
C 21	154.4

2 BODY MEASUREMENTS OF FISHES

For population analysis, food availability studies and prediction of sizes of fishes vulnerable to piscivorous fishes, equations relating total length of fishes to their maximum depth, to maximum width, to mouth width, and to weight are needed. It is proposed that weight in grams and the following measurements be made on all species of fish cultured in various countries.

(i) Length

It is recommended that total length only be used. This is defined as the overall length from the tip of the snout to the end of the tail.

(ii) Maximum depth

This measurement is the vertical dorsal-ventral distance measured at the point of maximum body depth.

(iii) Maximum body width

This is the horizontal distance from side to side of a fish measured at the point of greatest width.

(iv) Mouth width

This is the smallest horizontal internal width of the mouth which limits passage of fish-food organisms into the gullet of the fish. It is best measured by a set of inside calipers.

3 CONDITION OF FISHES

It is recommended that condition be expressed as relative condition using the LeCren condition factor:

$$Kn = \frac{W}{\hat{W}}$$

where W = weight of a fish of total length L_1 in a population

$\hat{W}$ = average weight of fish of the same total length L_1 computed from standard length-weight equation for all areas raising this species.

The standard length-weight equations and tables should be computed by FAO from length-weight data supplied by Research Stations in all countries where the species is important in pond fish culture.

For example if in a feeding experiment in Thailand, the average weight of Tilapia macrochir of 15 cm total length was 85.4 grams, while the average from the above standard length-weight equation was 63.6 grams for this length, then:

$$Kn = \frac{85.4}{63.6} = 1.34$$

thus indicating the condition was 1.34 times the standard average for this species.

This is much more meaningful than condition (C) determined by various formulae using as a basis:

$$C = \frac{W}{L^3}$$

In effect, the above C is merely a correction factor needed to relate L^3 to the volume of a fish. It therefore varies with species and is different for different lengths of the same species as the shape of a fish changes with length and/or other factors.

4 TESTS OF EFFICIENCY OF VARIOUS SPECIES OF FISHES IN POND CULTURE

An important aspect of pond fisheries research is the search for efficient species and efficient combinations of species. Any one species may differ in efficiency with different conditions. For purposes of comparison, it would be desirable to set up a uniform method of assessing the efficiency of different fishes at 3 levels: in unfertilized ponds, in fertilized ponds, and in ponds where fish are fed.

Since numbers of fish per hectare influence the results, it is suggested that three rates of stocking be tested, namely, 2,000, 4,000, and 8,000 fish per hectare.

Size of fish stocked also has been found to influence production. Consequently, it is suggested that fish stocked be in the 7-cm group.

Rates of feeding influence efficiency of food conversion. For uniform results, the feeding rate should be set at 3 percent of the standing crop of fish per day, with the feed on a dry-weight basis. Feeding rates should be readjusted every two weeks to 3 percent of the estimated standing crop.

The plan of experiment would be as follows:

Treatment	Number of fish stocked per ha		
Unfertilized	2000	4000	8000
Fertilized	2000	4000	8000
Fish fed	2000	4000	8000

Length of the experiment should be 120 days, after which time the fish should be counted, measured and weighed. The results should be reported in number and weight of fish in cm-groups.

Daily water temperature readings should be made with maximum-minimum thermometer set at 0.5 metre depth. The composition and moisture content of the feed used should be reported. Fertilization should be with superphosphate, placed on a platform 0.3 m under water, using the equivalent of 9 kg P_2O_5 per ha at the beginning of the experiment and another application four weeks later.

5 COMMON NAMES OF FISHES

There is a definite need for a list of accepted common names for fresh-water fishes of commercial importance in the three official languages used by FAO, namely English, French and Spanish. It is recommended that a committee be appointed to draw up a tentative list of common names to be submitted to the various countries involved for approval.

6 NUMBERING SYSTEM FOR TILAPIAS AND OTHER SPECIES

With the present rapid international traffic in live fish and the confusion and rapid obsolescence of scientific names of tilapias and other species it will be quite difficult for future readers of current scientific papers to know the exact species being discussed.

It is suggested that a numbering system be set up to enable future identification of the species. This should be coded so that the identifying number includes the continent, country, river watershed and year the fish was first obtained in its natural habitat. The coding might utilize Roman numerals for the continent, with two spaces being utilized for Arabic numerals giving in order the country where found and the river watershed, followed by the four numerals giving the year obtained.

The continents could be distinguished as follows:

I	Asia
II	Africa
III	North America
IV	Central America
V	South America
VI	Europe
VII	Australia-New Zealand
VIII	Oceania

The river systems and contries, in each continent would be given numbers from 01 to 99, with the year at the end. River systems and countries would be listed and numbered in alphabetical order, using English names. For example Tilapia macrochir 1105021956 would indicate a fish from Africa, from country 05 (eg. Congo), from river system 02 (eg. Ubangi River) in 1956, which at that time was known as T. macrochir. If the above fish was obtained from Hawaii in 1966, then it might be designated T. macrochir VIII 96911966 - II 05021956.

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STANDARDIZATION OF BIOLOGICAL STUDIES IN FISH CULTURE RESEARCH

by

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Abstract

The type and details of biological data required on various aspects of fish culture are described and proformae proposed for their collection. Studies on the habitat for cultivation, species for cultivation, procurement of stocking material and methods of cultivation are covered. The need for ensuring comparability of data by the use of uniform methods in different research centres is emphasized.

NORMALISATION DES ETUDES BIOLOGIQUES EN MATIERE DE RECHERCHE PISCICOLE

Résumé

La communication décrit en détail le type de données biologiques requises pour divers travaux de pisciculture et propose des modèles pour l'établissment de ces données. Elle contient des études sur l'habitat et les espèces convenant à l'élevage, la fourniture de sujets de repeuplement et les méthodes de culture. L'accent est placé sur la nécessité de veiller à la comparabilité des données grâce à l'utilisation de méthodes uniformes dans les différents centres de recherche.

NORMALIZACION DE LOS ESTUDIOS BIOLOGICOS EN LAS INVESTIGACIONES PISCICOLAS

Extracto

Se describen la clase y detalles de los datos biológicos que hacen falta en relación con los distintos aspectos de la piscicultura, y se proponen para los formularios adecuados para registrar aquéllos. Abarcan estudios sobre el habitat, especies de cultivo, obtención de material de repoblación y métodos de cultivo. Se pone de relieve la necesidad que existe de asegurar la comparabilidad de los datos mediante el empleo de métodos uniformes en los distintos centros de investigación.

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Biological studies essential to Scientific fish culture may be considered under the following sections:

(i) Habitat for cultivation
(ii) Species for cultivation
(iii) Procurement of stocking material
(iv) Methods of cultivation

Details of studies to be carried out under each of the above sections may be briefly outlined below:

1 HABITAT FOR CULTIVATION

1.1 Hatchery ponds

Small, shallow ponds with gentle or no flow of water.

Source of water ______________________________

Date of filling in ____________________ Depth of water ____________

Flow of water ______________________________

Water conditions (6 hourly records).

Date	Time	Temperature °C	pH	D.O.	CO_2

Eggs of (Species) ______________________________

Size of parents:

Sex	Length (cm)	Weight (g)
Male		
Female		

Sex (Male: Female) ratio by number ______________________

Weight ______________________

Eggs laid/fertilized on (date/time) ______________________

Methods of spawning ______________________

____

Eggs kept for hatching on (date/time)__________

Egg container (hatchery tray) - Length__________Width__________

Depth__________

No. of eggs kept per container__________

Percentage of fertilization__________

Time of hatching (date/time)__________

Nature of hatchlings__________

Length of hatchlings in mm

1		6		11		16		21	
2		7		12		17		22	
3		8		13		18		23	
4		9		14		19		24	
5		10		15		20		25	

Removal of hatchlings (date and time)__________

No. of hatchlings per container__________

Percentage of hatching__________

Water conditions a few hours before keeping eggs for hatching and at six hourly intervals after keeping for hatching to be recorded. This is to continue till the removal of hatchlings.

Sample of hatchlings for measurements to be collected when majority of eggs are found to have hatched. Measurements are preferably recorded within 3-4 days of preservation. Preservation in two percent formalin.

Details of hatchery tray/container to be recorded in detail (material with which made, mesh size, length, breadth, depth, depth of water in the container, etc.)

In the case of the common carp if 'kakabans' are used, size of each 'kakaban' to be given.

From the weight of female spawner(s), expected weight and number of eggs laid and number of 'kakabans' used estimate the number of eggs sticking on each 'kakaban'.

When weeds are used as egg collectors, record species and weight of weeds used. Note weight of weeds introduced in each hatching tray. From the expected weight/number of eggs laid and the total weight of weeds used, the number of eggs sticking on known weight of weeds can be estimated.

Percentage of hatching to be determined by taking a small sample of laid eggs from the 'kakabans' or weeds.

In the case of Indian and Chinese carps enumeration of laid eggs is easily done by measurement with a small container of known volume and by counting the number of eggs the container can hold. Percentage of fertilization is also determined by taking a similar sample and segregating the fertilized and unfertilized ones.

Number of hatchlings is also determined by actual counts of those in a small container of known volume, for example a small perforated cup of one or two ml capacity.

1.2 Nursery ponds

Preparation of nursery ponds for receiving stock should be started in advance so that natural food in adequate quantities would be produced and available at the time of stocking.

When the nurseries are perennial, eradication of the existing stock of fish, if any, including predatory forms is the first step.

Poisoning and clearing

Date of poisoning ____________________

Poison used ____________________

Area of water surface ____________________

Depth of water: Maximum ____________________

Average 1/ ____________________

Approximate water content ____________________

Dose of poison ____________________

Quantity of poison applied ____________________

Mode of application ____________________

Time of application ____________________

Water conditions during and after poisoning:

Death of fish (time)

(Vide toxicity tests)

Commencement	Peak	End

[1/] A series of soundings, at fixed intervals, in lengthwise and breadthwise cross section of the pond/tank are taken and averaged.

Species of fish killed

Species	No.	Range of length

Effect of poison on

Crabs______________________________

Molluscs____________________________

Worms_______________________________

Plankton____________________________

Toxicity tests of water

Twenty four hours after poisoning collect water from the pond in three medium size glass troughs or jars and keep them in a cool shaded place. Introduce equal number of small specimens of selected test fish and record observations as follows:

Date of poisoning____

Date of toxicity test______________________________________

Reactions of test fish_____________________________________

Species of fish	Average length (cm)	Reaction, hours after introduction		
		6 hours	12 hours	24 hours

If mortality occurs or distress is shown by test fish within 24 hours of introduction the tests are to be repeated till the pond water becomes non-toxic.

Physico-chemical conditions of water in the treated pond may be determined at fixed intervals till toxicity disappears from water.

Water conditions		No. of days after poisoning					
	Before poisoning	1 day	2 days	4 days	6 days	8 days	Remarks
Temp. °C							
pH							
D.O.							
CO_2							
Alkalinity							

Toxicity of the treated water will gradually decrease. Ordinarily within a week of poisoning water conditions will return to normal. When Endrin is used, the toxicity remains for nearly a month. When toxicity is on the wane, the pond is manured for augmented production of fish food - plankton. Optimum production of plankton will be two to three weeks after manuring.

The following observations may be recorded during this phase.

(i) Particulars of manuring

As growth of fish food in the pond directly depends on the quality and quantity of manure applied, detailed records of manuring are to be maintained as follows:

Date of manuring ______________________________

Water surface area ______________________ sq m

Average depth of water ____________________ m

Approximate water content in the food ______________________________ m^3

Manure applied	Quantity applied (kg)	Dose	
		per ha	in ppm

Mode of application ____

____

(ii) Pond soil conditions

Conditions	Before poisoning	4 days after poisoning	Before manuring	2 days after manuring	7 days after manuring	2 weeks after manuring
pH						
Alkalinity						
Nitrogen						
Phosphorous						

(iii) Water conditions

Conditions	Before poisoning	4 days after poisoning	Before manuring	2 days after manuring	7 days after manuring	2 weeks after manuring
Temperature						
pH						
D.O.						
CO_2						
Alkalinity						
Nitrogen						
Phosphorous						

(iv) Bottom fauna: Sampled with a bottom grab; 3-6 samples taken from different places in the pond each time; number of organisms averaged and expressed as number per m^2 area

	(1)	(2)	(3)	(4)	(5)	(6)
Insects:						
______						
______						
______						
Worms:						
______						
______						
______						
Mulloscs:						
______						
______						
______						
Others:						
______						
______						
______						

(v) Nekton: Sampling to be done with a suitably devised 0.5 or 1.0 m^2 sampler 1-2 m deep and with a closing device at the bottom. The volume of water filtered can easily be calculated from the size of the sampler and the height of water column sampled. Observations may be recorded as follows:

Organisms	Before poisoning	No. per m^3 of water				
		1 day after poisoning	4 days after poisoning	7 days after poisoning	14 days after poisoning	21 days after poisoning
Backswimmers (Notonectidae)						
Waterscorpion						
Waterboatman (Ranatra)						
Beetles (Gybister)						
Eretes						
Beetle larvae						
Young prawn						
Fish fry						
Others						

(vi) Plankton: Plankton constitutes the most important source of fish food in the nursery pond and detailed records of the same are essential for intelligent interpretation of the results of rearing. Collections are to be carefully preserved and studied.

Collections may be made by filtering known volumes of water, not less than 50 litres, taken from one or more locations in the same body of water and filtering the same through a No. 21 standard bolting silk tow-net. The preserved collection is diluted to a convenient volume from which an aliquot of known volume is taken on a plankton counting cell and a total count made. Three such aliquot samples are counted and averaged. From these average counts, known volume of aliquot sample, diluted volume of collection and volume of water filtered, the number of organisms per m^3 or any unit volume can be calculated. The average counts may be recorded as follows:

Date of collection	(1)	(2)	(3)	(4)	(5)
Colour of water					
Volume of water (litres) filtered					
Diluted volume (cc) of collection					
Volume (cc) of sample for count					
Phyto-plankters Chlorophyceae ______________ ______________ ______________ ______________ ______________					
Bacillariophyceae ______________ ______________ ______________ ______________ ______________					
Euglenineae ______________ ______________ ______________					
Cyanophyceae ______________ ______________ ______________					

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	(1)	(2)	(3)	(4)	(5)
Others ______ ______ ______					
Zooplankters Protozoans ______ ______					
Rotifers ______ ______ ______					
Cladocerans ______ ______ ______					
Copepods ______ ______ ______					
Ostracods ______ ______ ______					

	(1)	(2)	(3)	(4)	(5)
Phyllopods					
Hydracarinae					
Insects and larvae					
Fish eggs or larvae					
Others					
Predominant phytoplankters					
Predominant zooplankters					

Plankton collections, before and after poisoning, are to be made at the same time as water samples for analysis are made. Plankton position in the pond just prior to application of manure is to be recorded. After manuring, collections are to be made 1, 2, 3, 5, 7, 10, 15, 20, 25 and 30 days after manuring. Within 15 to 20 days of manuring production of zooplankton will be appreciable, when the pond has to be stocked with fish seed for rearing.

Twenty four hours before stocking the pond a plankton collection is made to assess the quality and quantity of plankton available. A similar sampling of aquatic insects is also made at the same time.

A further sampling for plankton and insects just a couple of hours before the time scheduled for stocking the pond would reveal the extent of success of the insect control treatment and its effect, if any, on plankton.

1.3 Rearing ponds

The same techniques as for preparation of nursery ponds have to be adopted for rearing ponds also and data on various biological aspects are to be maintained in the same way as for nursery ponds. Manuring of rearing ponds need be carried out 10 to 15 days after manuring nursery ponds.

1.4 Stocking ponds

The following should be a guide for recording basic data that would enable proper assessment of survival, growth and production in stocking ponds

Locality____________________

Soil type of the locality____________________

Name of pond/tank____________________

Area in ha__________ a) during summer (minimum)__________ha

b) during rainy season (maximum)__________ha

Depth of water: a) minimum, during summer__________m

b) maximum during rainy season__________m

Source of water____________________

Inlet if any: Width__________

How protected?__________

Outlet if any: At what level?__________ Width__________

How protected?__________

Age of the pond (how many years since constructed)__________

Bottom silt: Depth__________m Colour__________

Smell__________ Consistency__________

Macrovegetation

Species	Extent of infection	During which month of the year

Schedule of manuring

Date of application	Manure applied	Quantity applied (kg)	Dose per ha

Schedule of artificial feeding

	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Frequency of feeding (daily, alternate day, once a week, etc.)												
Feed given												
Quantity given at a time (kg)												
Total quantity given during the month												

Soil conditions

Sampling once a month; application of manure during the month, if any, to be at least two weeks before or after the sampling.

	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
pH												
Calcium (mg/100 g)												
Nitrates (mg/100 g)												
Phosphates (mg/100 g)												

Water conditions

Fortnightly analysis of water samples to be carried out so that fluctuations in nutrient status of the pond could be correlated with fish production

Month	Fortnight	Water Temp. (^oC)	pH	Dissolved O_2	Free CO_2	Total alkalinity	Nitrates	Phosphates	Chlorides

Ordinarily collections are to be made on the 7th and 22nd of each month. The time of collection should also be uniform throughout, preferably at 10.30 - 11.00 a.m.

Bottom fauna

Monthly records of fluctuations in bottom fauna may be maintained, the samplings being made at the same time when soil samples are taken for chemical analysis.

Each time three samples at three different depths of water may be taken and the number of organisms recorded separately. Sample I, would be nearer the margin and from shallow water; sample III at the deepest portion near the centre of the pond and sample II at a point between I and III.

Month	No. in square metre area											
	Insects			Worms			Molluscs			Others		
	I	II	III	I	II	III	I	II	III	I	II	III
J												
F												
M												
A												
M												
J												
J												
A												
S												
O												
N												
D												

Nekton

Sampling as in nursery and rearing ponds; but only once a month. Average of three samples to be recorded every month as follows:

Months	No. per cubic metre of water							
	Back swimmers	Water-scorpion	Water-boatman	Beetles	Beetle larvae	Young fish	Young prawns	Others
J								
F								
M								
A								
M								
J								
J								
A								
S								
O								
N								
D								

Fish

a) Removed during poisoning and clearing

Species	No.	Range of length (cm)	Average length (cm)	Average weight (g)	Total weight (kg)	Remarks (eradication complete/not complete)

2 SPECIES FOR CULTIVATION

Careful and thorough assessment of selected species is essential before they can be recommended for cultivation. Species of fish now being cultivated may not necessarily be the best available and so a methodical assessment of each species on the pattern given below should facilitate a more rational selection. This assessment would include careful studies on all aspects of the natural history and biology of the species and some preliminary studies on its growth in ponds:

Family____________________

Genus and species____________________

Natural distribution____________________

Habitats____________________

Relative abundance____________________

Maximum size reported____________________

Predominent size in commercial catches____________________

Rating as a table fish____________________

2.1 Food and feeding habits

A complete series of specimens, from early post-larval stages, right up to full grown adult, of about 300 to 500 specimens, collected from different habitats during different months of the year have to be examined for their gut contents. As far as possible these specimens should be freshly caught, killed and immediately preserved on the spot so that the gut contents would not undergo any changes between the time of capture and preservation. Smaller specimens may be preserved entire but the larger ones are examined first for relevant features, dissected and the gut taken out and preserved separately. Analysis of gut content may be made adopting any of the well known methods and observations recorded as follows:

Serial No.	(1)	(2)	(3)	(4)	(5)	(6)
Date of collection and time						
Habitat						
Length (cm)						
Weight (g)						
Length of gut (cm)						
Weight of gut (cm)						
Extent of feed						
Gill rakers No						
Gill rakers Length						

Gut contents:

Serial number of specimen____

Diluted volume of gut contents (cc)________________________________

Volume of sample for analysis_____________________________________

Organisms	No. in sample	Total No. among gut contents	Percentage in total feed	Remarks

A critical study of the analysis of gut contents will give details of the food and feeding habits of the species during different stages of its life history. This information is necessary to determine its compatibility with other species as also to initiate steps to provide the type of food required for its optimum growth.

2.2 Maturity and fecundity

A sufficiently large number of specimens from different habitats have to be examined during different months of the year to determine the minimum size at sexual maturity, the breeding season and fecundity of the species. Observations on size and maturity may be recorded as follows:

Month	Size of specimens examined				Sex	Stage of maturity	Weight of gonad (g)	
	length (cm)		weight (g)					
	Range	Average	Range	Average			Range	Average
J								
F								
M								
A								
M								
J								

Basic data on the fecundity of the species may be recorded as follows:

No.	Date	Habitat	Length (cm)	Weight (g)	Stage of maturity	Weight of ovaries (g)	Total No. of ova in the ovaries	Diameter of ova (mm)

Gravid specimens are selected for fecundity determination. Each specimen is measured and weighed. The ovaries are then carefully dissected out and weighed. A 15-25 g sample of the ovary is then taken and carefully preserved in formalin. When the ova are hardened by preservation, three samples, each weighing 2 to 3 g are weighed out from the preserved sample, and the ova separated carefully and counted. Total number of ova in the ovaries is calculated from the average number of ova from unit weight of the ovaries and the total weight of the two ovaries. The diameter of at least 25 ova from a sample is measured under a microscope.

Diameter of ovarian eggs in mm

Calculated volume of 1,000 ova (cc)______________________________

No. of ova per cc____

2.3 Breeding season and habits

Some idea of the breeding season of the species would be available from size and maturity data. More specific information may be recorded as follows:

Breeding habitat	Breeding period (months)	Generally prevailing weather conditions during breeding
Rivers		
Lakes/reservoirs		
Ponds/tanks		
Estuaries		
Other habitat		

The exact location of spawning grounds would be necessary for exploitation of natural seed resources. Details of spawning habits may be recorded as follows:

Time of the day at spawning ____

Weather conditions one day before spawning_____________________________

____

Weather conditions at the time of spawning_____________________________

____

Colour of water in spawning ground_____________________________________

Depth of water in spawning ground______________________________________

Flow of water in spawning ground_______________________________________

Nature of substratum in the spawning ground____________________________

____

Location of the spawning ground

Species forming the spawning congregation

Number of specimens forming the spawning congregation

Predominent species

Size range of spawners

	Length	Weight
Males		
Females		

Sex ratio in spawning congregation

Spawning

Nature of eggs: Pelagic/demersal/adhesive/non-adhesive. Diameter in mm of fertilized, swollen eggs: (sample of 25 eggs)

1		6		11		16		21	
2		7		12		17		22	
3		8		13		18		23	
4		9		14		19		24	
5		10		15		20		25	

Calculated volume of 1,000 eggs (cc)

Number of eggs per cc

Weights of 1,000 eggs (g)

2.4 Life history

A brief account of the embryonic, larval and post-larval development of the species may be recorded, supplemented by illustrations:

Water conditions				Period of incubation (hr)
Temperature °C	pH	D.O.	CO_2	

Colour of laid egg ____________________

Embryonic stages

(Range of water temperature at which development takes place, to be recorded)

(Diameter of the egg proper and diameter including vitelline space)

Stage of development	Age in hours/minutes after fertilization
First cleavage	
Second cleavage	
Third cleavage	
Fourth cleavage	
Morula state	
Commencement of gastrulation	
Yolk invasion half completed	
Yolk plug stage	
Early indication of embryo	
Elongation of yolk mass commences	
Appearance of myotomes	
Differentiation of head and tail regions	
Appearance of optic cups and number of myotomes	
Appearance of lens in optic cups	
Elongation of tail from yolk mass and number of myotomes	
Appearance of Kupfer's vesicle and number of myotomes	
Appearance of auditory vesicles and number of myotomes	
Appearance of auditory concretions and number of myotomes	
Commencement of movement and number of myotomes	
Indication of mouth	
Pigmentation of eyes	
Appearance of chromatophores	
Appearance of pectoral fin buds	
Hatching	

Larval Stages

Characters (all measurements in mm)	Differentiation during phases (hr after hatching) of larval life					
	0-1 hr	6.0 hr	12.0 hr	24.0 hr	36.0 hr	48.0 hr
Total length						
Height of body at pectoral level						
Length of yolk sac						
Maximum height of yolk sac						
Number of pre-anal myotomes						
Number of post-anal myotomes						
Diameter of eye						
Colour of eye						
Nature of auditory concretions						
Position of mouth						
Mouth functional or not						
Barbels						
Pectoral fin rudiment						
Directive movement						
Hind tip of notochord						
Distribution of chromatophores						
Commencement of feeding						

The above observations may be extended at 12 to 24 hr intervals until the yolk is fully absorbed and the larva enters the post-larval stage.

Post-larval stages may be collected by rearing larvae under laboratory conditions and or in ponds. When reared under laboratory conditions care should be taken to feed the larvae with adequate live food so that their growth and differentiation would be almost normal. Samples from a pond would always be preferable to laboratory-reared samples. Post-larval features up to complete differentiation of all fins may be recorded as follows:

Post-larval stages

Characters (all measurements in mm)	Differentiation during phases (days after hatching) of post-larval life					
	4	7	10	15	20	25
Total length						
Length of head						
Diameter of eye						
Height of body at pectoral level						
Position of mouth						
Nature of lips						
Barbels						
Hind tip of notochord						
Embryonic fin fold						
Dorsal fin						
Rays in dorsal fin						
Caudal fin						
Rays in caudal fin						
Anal fin						
Rays in anal fin						
Ventral fin						
Rays in ventral fin						
Pectoral fin						
Rays in pectoral fin						
Caudal spot						
Lateral pigment line						
Other characteristic pigment concentrations						
Pigment on fins if any						
Scales:						
Appearance nature						
Distinguishing colouration, if any, in live specimens						
Any other feature						

Assessment of the species for purposes of profitable cultivation would necessitate preliminary information on its growth and production when cultivated alone and also in combination with selected species of compatible habits. Such information could be gathered on the same lines as indicated under the section on methods of cultivation.

3 PROCUREMENT OF STOCKING MATERIAL

Methods of procurement of stocking material may be considered on the basis of breeding habits of the species of fish, e.g., (i) species which normally breed in ponds; (ii) species which could be induced to breed in ponds; (iii) spcies which breed only in natural habitats such as lakes, rivers, estuaries, backwaters, etc.

3.1 Species normally breeding in ponds

Detailed records of the nature, extent and success of spawning have to be carefully recorded for critical study.

Genus and species____________________

Size of breeding ponds: Length (m)__________Width (m)__________

Area (ha)__________Maximum depth of water (m)__________

Depth of water in the breeding area (m)__________

Area of marginal shallows__________

Nature of substratum in spawning area__________

Fish population in the pond at the time of spawning

Species	Number	Average length (cm)	Average weight (g)	When introduced

Water conditions and fish food during and after spawning

	At spawning time	One day after spawning	3 days after spawning	5 days after spawning	10 days after spawning
Water temperature (°C)					
pH					
Dissolved oxygen					
Free CO_2					
Total alkalinity					
Plankton: Volume of sediment in 50 litres of water					
Percentage of phytoplankton					

	(1)	(2)	(3)	(4)	(5)
Predominent zooplankton					

Extent of spawning:

Breeding in the pond:

	Males	Females
Number		
Average length (cm)		
Average weight(g)		
Total weight (kg)		
Age (years)		
Grown in the pond or introduced		
If introduced, when		

Potential spawning capacity of stock

Number of females____________________

Average weight (g) ____________________

Average weight of ovaries (g)____________________

Average total number of ova per female____________________

Average number of eggs expected to be laid by a female at one spawning____________________

Number of female breeders in the spawning congregation____________________

Total number of eggs expected to be laid at the particular spawning____________________

Total number of eggs laid as assessed by sampling____________________

In cases where eggs are scattered all over the spawning area, or where eggs are sticking on to weeds or some substratum sampling representative unit areas would be feasible. If the spawning area is also known, approximate number of eggs laid can easily be calculated from the average figure for unit area. In the case of nest-builders or mouth breeders such assessment is comparatively easy as selected samples can be examined but it may be difficult to return the samples for successful hatching.

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Spawning success

Percentage of fertilization of eggs laid______________________________
This is to be determined by sampling at fixed intervals after spawning until hatching.

Hr after spawning	Sample examined			Percentage of fertilization	Remarks
	Total number	Number of developing eggs	Number of dead eggs		
2 - 3					
12					
24					
36					
48					

Percentage of hatching______________________________

Approximate total number of hatchlings____________________

Results of hatching under natural conditions may be compared with results under laboratory conditions where fluctuations may not be very marked. Samples of eggs taken from the spawning ground are kept in shallow containers in the laboratory, with periodic change of water so as to maintain the dissolved oxygen level for successful hatching. Water conditions such as temperature, pH, D.O., and CO_2 should be periodically determined. These samples would be examined at the same time as the field samples and the results compared.

The survival of hatchlings or larvae up to the post-larval stage or until the yolk is fully absorbed is separately estimated. In the case of carps, under natural conditions, the larvae will start moving almost within a day after hatching. Sampling under such conditions may not be representative and it would not be possible to assess the mortality during the period. Mortality due to factors other than predation may be estimated by keeping known number of hatchlings in small cloth or similar enclosures in the pond itself and examining these at desired intervals.

Enclosure number	Number of hatchlings	Lapse of time (hr) after hatching	Number of live hatchlings	Percentage of mortality
		6		
		12		
		24		
		36		
		48		

In the case of nest builders, mouth breeders and those having other means of parental care, sampling selected post-larval broods would enable calculation of mortality/survival from the time of fertilization up to the post-larval phase. Predation is not a major factor in these cases.

When initial rearing is in the spawning pond itself, spawning success is assessed as the number of two-weeks' old juvenile fish obtained per every million eggs laid. This is a total assessment by seining or dewatering the pond. When larvae are transferred to special nursery ponds this assessment would be more of rearing success than of spawning success.

3.2 Species that are induced to breed in ponds

Common carp, though a pond breeding species, require specific inducement such as egg collectors for successful breeding. It is well known that production of stocking material resulting from wild spawning of common carp is very limited and specialized techniques for breeding the fish have been developed for large scale production of stocking material. Detailed records of carp breeding and production of stocking material may be maintained as follows:

Particulars of breeding stock______________________________

____

Age (in years): Male______________ Female______________

Pond/habitat in which stock was reared________________________

Male______________ Female______________

Sexes segregated: Yes/No

If 'yes' for what period prior to
release in spawning pond____________________________

Artificial feed, if any given__________________________

____

Earlier spawning date________________________________

Present condition:

	Male	Female
Length (cm)		
Weight (g)		
Vent		
Abdomen		
Abdominal ridge		
Oozing		
General assessment		

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Breeding habitat

Pond/cistern/wooden tub ____________________

Size (m) length ____________ Width ____________ Depth ____________

Source of water: ____________________

Water quality	Temperature	pH	D.O.	CO_2	Alkalinity	Colour/turbidity
While introducing breeders						
After spawning						
During removal of eggs for hatching						

Depth of water (m) ____________________

Flow if any ____________________

____

Brood stock

Time of day when introduced ____________________

Sex ratio by number ____________ ♂ ____________ ♀ ____________

____________ by weight ♂ ____________ ♀ ____________

Weight (kg) of breeders introduced

Males	Number	Total weight
Females		

Number of eggs expected to be laid by the females introduced ____________________

Egg Collectors

Kakabans: Material used ____________________

____

Length (m) ____________ Width (m) ____________

Number of kakabans ____________________

Weeds: Species ____________________

Quantity introduced (kg) ____________________

Spawning: Commencement (date/time) ____________________

End (date/time)____

Spawned females						Unspawned females	
Number	Weight before spawning	Weight after spawning	Difference in weight	Weight of eggs laid	Approx. number of eggs laid	Number	Difference in weight if any

The difference between the weight of the female before and after spawning will represent the weight of eggs laid, plus the weight of faecal matter excreted during the period. While calculating the number of eggs laid an allowance for the weight of faecal matter has to be made on the basis of total weight of the breeders. Some idea of the weight of faecal matter excreted would be obtained from the difference in weight of the unspawned females.

Spawned females and males are transferred back to the stock pond. The unspawned ones, if in good condition may be kept, with fresh males, for another day for breeding. If they still do not breed they are promptly transferred to stock ponds.

The eggs laid are to be sampled to determine the percentage of fertilization as detailed above. Samples are to be measured as follows:

Outer diameter (mm)										
Diameter (mm) excluding vitelline space										

(Sample of at least 30 eggs to be measured)

Number of developing eggs____________________________________

Hatching operations

Time of removal of eggs from spawning pond to hatchery pond________________________________

Period (hr) between end of spawning and removal of eggs for hatching____________________________

Period (hr) between commencement of spawning and removal of eggs for hatching____

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Hatchery pond:

Length ______________ Width ______ ______ Depth ________________

Depth of water ____

Flow of water ____

Number of kakabans kept in the pond ______________________________

Number of live eggs on them ___________________________________

Quantity of weeds distributed in the pond (kg) _______________________

Number of live eggs sticking on to them ____________________________

Size of hatchery unit ______________________________________

Material with which made ____________________________________

Depth of water inside the hatchery unit (m) _________________________

Quantity of weeds distributed in the pond (kg) _______________________

Number of live eggs introduced in each _____________________________

Hatching (date/time) _______________________________________

Period of incubation (hr) ____________________________________

Length of hatchlings (Sample of 30; measurements in mm)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

Yolk absorption completed by (date/time) ____________________________

____________________ hr after hatching.

Survival up to post-larval stage

Hatchery unit						
Number of eggs kept for hatching						
Number of post-larvae obtained						
Survival (%) from fertilization to yolk absorption						

Length of post-larvae (sample of 30; measurements in mm)

Weight of 1,000 specimens______________________________g

Rearing in ponds

Aspects of preparation of the pond have already been covered under habitat

Pond Number____

Dimensions: Length______________ Breadth________________Depth______________

Depth of water_________________________ flow of water________________________

Source of water____

Details of manuring, nutrient status of soil and water and fish food position to be recorded as detailed under habitat.

Insect control measures adopted (date/time)____________________________________

__________ ____

Stocking: Date/time____

Number stocked____

Number per ha of water area____

Number per m^3 of water ____

Harvesting

In the case of ponds used as hatching-cum-nursery ponds the number of fry obtained would represent the survival from the time of fertilization of eggs to the fry stage. In those cases where post-larvae were released for rearing the harvest would represent the survival during post-larval rearing only. In all cases representative samples are to be weighed and measured.

Date of harvesting____

Rearing period (days)____

Samples for weighing (100 each)

	Sample 1	Sample 2	Sample 3	Average weight per 100
Weight in g				

Measurements of total length: (Sample of 50; measurements in mm)

Production

Pond Number	Number harvested	Survival percent	Total weight of harvest (kg)	Production			Calculated production/ ha/year	Average length (mm)
				Number per ha	Weight per ha	Average daily per ha		

3.3 Induced breeding by injection of hormones

Pond reared Indian and Chinese carps (*Catla catla*; *Labeo rohita*; *Cirrhina mrigala*; *Hypophthalmichthys molitrix*; *Ctenopharyngodon idella*; *Aristichthys mobilis*; etc.) are now induced to breed by the injection of pituitary hormones. However, considerable work remains to be done for fully standardizing the techniques and making them dependable under field conditions to ensure commercial production of fish seed. Proper recording of detailed observations on all aspects of this work will go a long way in standardizing the techniques.

3.3.1 Collection and storage of pituitary glands

Pituitary glands are to be individually preserved and all particulars of the donor fish are to be recorded as follows:

Donor species				
Serial number				
Habitat in which grown				
Caught on (date/time)				
Length (cm)				
Weight (g)				
Sex				
Stage of maturity				
General condition				
Date of collection of pituitary gland				
Interval between collection of fish and collection of gland (hr)				
How preserved during the period?				
Size of pituitary gland (length X width) mm				
Weight of pituitary gland (mg)				
Preserved in				
Preservative renewed on (date)				
Preserved at room temp. or lower temp.				
Used for injection on (date)				
Period of preservation (days)				

Details of injections administered and results obtained may be maintained as follows:

Recipient species____

Habitat where breeders matured______________________________

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Size	Sex	Length (cm)	Weight (kg)
	Male		
	Female		

Breeding environment:

Cistern/Pond/Reservoir/Canal/River________________

Size________________

Depth of water________________

Condition of water:

Flowing/stagnant/fresh/clear/turbid/with bloom.

	Temp.	pH	D.O.	CO_2	Alkalinity
At first injection					
At second injection					
At spawning					

Breeding enclosure:

Size________________

Material with which made________________

Depth of water inside________________

Pituitary glands used for injection

	For first injection	For second injection
Donor species of glands		
Serial number of glands used		
Total weight of glands used		

Injection and spawning

Injection	First Male	 Female	Second Male	 Female
Date Time (hr)				
Dose (mg/kg)				
Weight of glands required (mg)				
Concentration of glands in extract (mg/cc)				
Volume of extract injected (cc)				
Weather conditions				

Interval between first and second injection________________________hrs

Date and time of spawning____________________________________

Interval between second injection and spawning____________________hrs

Eggs: Naturally fertilized/artificially fecundated

Weight of breeders:

	Female	Male
Before spawning (g)		
After spawning (g)		
Difference in wt.(g)		
Weight of gonads after spawning		
Whether spawning complete/partial		

Calculated number of eggs laid (weight of eggs laid x number of eggs per g wt of ovaries).

Actual number laid____

Volume of sample cup (cc)	Number of eggs per cup			Number of eggs per cc	percentage of fertilization	Total number of cups measured	Total number laid
	Live	Dead	Total				

Diameter of eggs (inner/outer) in mm (sample of 30)

Total number of developing eggs____

Percentage of fertilization may be checked by sampling as development progresses.

3.4 Species spawning in natural habitats

Various species of Indian and Chinese carps, major species of brackish water food fishes like Hilsa, Chanos and Mugil among others, come under this category. Location of seed concentration centres, timely exploitation of such concentrations, storage and transport to rearing centres are the major activities involved in fish culture.

Indian and Chinese carps breed in flooded rivers during monsoon months. Millions of eggs, hatchlings and early post-larvae washed down the current, are caught in specially devised nets, transported over long distance to nursery ponds and reared. Particulars of river spawn collection may be detailed as follows:

River system ____________________

Name of collection centre ____________________

Location ____________________

Condition in summer (dry/with water) ____________________

Substratum ____________________

Slope from bank ____________________

Width of collection ground ____________________

Date of first flooding during the season ____________________

Date of collection ____________________ time ____________________

Depth of water on collection ground ____________________

Flow of water ____________________ m per sec.

Colour of water ____________________

Water level ____________________ Rising/Falling ____________

Number of nets operated ____________________

Size of nets used, length ____________________ width of mouth ____________________

Depth of mouth ____________________ Diameter at cod end ____________________

Length of 'tail cloth' ____________________

Net fixed at what depth from surface? ____________________

Net cleared at what intervals? ____________________

Duration of heavy collection (hr) ____________________

Number of 'hauls' per net during the period ____________________

Handling of spawn ____________________

Capacity of 'cup' used for measuring spawn (cc) ____________________

Number of spawn per cup ____________________

Average number of cups of spawn obtained per net ______________ in ______________ hr

Total collection ____________________ cups ____________________ No.

Size of spawn collected (samples to be measured and measurements recorded in tabular form)

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Collection of young ones of brackish water fishes

Name of centre______________________________

Date of collection______________________________

Species______________________________

Location of centre______________________________

Within tidal influence: Yes/No

State of tide at collection______________________________

Depth of water at collection ground______________________________

Method of collection______________________________

Size of material collected (by examples)______________________________

Quantity/No. collected______________________________

Duration of collection (hr)______________________________

Temporary storage : container______________________________

Volume of water______________________________

Number of fish per container______________________________

Duration of storage (hr)______________________________

Mortality during storage______________________________

4 METHODS OF CULTIVATION

Stocking material are transported as spawn, larvae, fry or fingerlings. When the distance involved is short and the number required is small, transport is easy in open containers. When large quantities are to be transported over long distances, methods of economic transport ensuring maximum survival are to be adopted. Transport requirements of different species of fish differ from one another and also from stage to stage and this phase of activity therefore calls for early standardization of techniques so as to avoid wastage. Experiments and observations on transport of young fish may be recorded in detail on the lines indicated below:

Species transported______________________________

Nature of stocking material transported: eggs/larvae/post-larvae/fry/fingerlings

Size: (length in mm of a sample of 30)

Range of length (mm)____________________ Average length (m)____________________

Weight of 100 (g)____________________ Average weight (g)____________________

Approximate age (days)______________________________

Collected from______________________________

How collected ____________________

Date/time of collection ____________________

Conditioning, if any, (duration in hr) ____________________

Interval between collection and packing (hr) ____________________

	Temp. °C	Water condition			Alkalinity
		pH	D.O.	CO_2	
In the rearing pond					
In the pond where conditioning was done					
Of water used for packing					

Time of packing ____________________

Shape/size of container ____________________

Volume of water in container ____________________ l

Number of young fish introduced ____________ weight ____________ g

Volume of oxygen introduced ____________________ l

Under what pressure? ____________________

Total weight of packed container with fish and water ____________________ kg

Mode of Transport : by road/by rail/by air

Duration of transport : (Time taken from packing to opening of container for release in pond) ____________________ hr

Date	Time	Water condition in container on opening				
		Temp.	pH	D.O.	CO_2	Alkalinity

Condition of fish on opening container at destination ____________________

____

Mortality (No.) ____________ Percentage ____________

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When short distance transport in open carriers is undertaken the additional information to be recorded is only the details of complete or partial renewal of water en route. This should include the quality of water used also.

Basic preparation of the habitat for rearing has already been dealt with. Other aspects of cultivation will be supplementing natural food by artificial feeding; manipulation and preventative/curative measures against infection and disease.

The main principles in selecting artificial feed are easy availability and low cost. Whatever feed is selected its use should be on a common pattern so that the results would be comparable.

Phase of cultivation: Nursery pond/Rearing pond/Stocking pond/Brood or stock pond.

Artificial feed ____________________

Nutrient value (percentage)

Feed item	Water	Protein	Fat	Carbo-hydrates	Total digestible nutrients

Size of pond ____________________

Water content ____________________ m^3 ____________________

Water stagnant/flowing __________

If flowing - rate of flow ____________________

Stock of fish: No. ____________ Average length (cm) ____________

Average weight (g) ____________

Total weight ____________ kg

Daily ration of artificial feed: actual quantity ____________ kg

as percentage of weight of stock ____________

Mode of feeding ____________________

Frequency of feeding (how many times a day) ____________

The effect of continued artificial feeding on water quality, plankton and fish has to be periodically determined. Weekly determination of water quality and plankton and fortnightly sampling of fish to determine the increment in weight due to feeding may be made. The quantity of daily feed to be given would then be determined every fortnight on the basis of the weight of stock at the end of each fortnight. After a specified period of feeding the results may be assessed as follows:

	1st fortnight	2nd fortnight	3rd fortnight
Area of the pond			
Stock introduced (No.)			
Average length of stock at commencement of feeding (cm)			
Average weight (g)			
Total weight of stock in the pond (kg)			
Duration of feeding (days)			
Feed given per day (kg)			
Total feed given during the period (kg)			
Number of fish recovered at the end of feeding period			
Percentage of survival			
Average length attained (cm)			
Average weight attained (g)			
Average increase in weight (g)			
Total weight of stock (kg)			
Net increase in weight of stock (kg)			
Average increase in weight in the pond per day			
Average increase in weight per ha per day			
Calculated annual increase in weight per ha/year			
Conversion ratio (weight of feed: weight increase)			

Artificial feeding may be for assessing the value of particular feeds or for assessing the response of selected species to particular feeds or for increased production. Detailed records as indicated above would facilitate analysis of data from all required aspects.

Manipulation of stock in the pond is an important step in proper cultivation. The stock to be introduced into the pond has to be determined on the basis of the inherent fertility of the pond, the normal growth of the species stocked and the quantity of manure or artificial feed proposed to be introduced. Different combinations of species at different stages and in different densities have to be tried before a suitable combination can be arrived at.

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Pond No.________________________Area__________________________

Date of stocking____

Species stocked	Number	Average length	Average weight	Total weight	Stock per ha	
					Number	Weight

Details of preparation, manuring and feeding, if any, are to be recorded as earlier specified.

Sampling would be done every month so that the growth achieved may be assessed. If the growth becomes poor it is an indication that the stock may have to be thinned out either of all the species or only of the particular species showing poor growth. Details of such fish removed and the effect of this removal on the left over stock have to be carefully assessed during subsequent samplings. At the end of the specified period of growth the entire stock is harvested and particulars noted for ascertaining the survival and growth of the various species.

Particulars	Species in the combination			
Average length at stocking (cm) Average weight at stocking (g) Number stocked Total weight (kg)				
Period of growth (days) Date of thinning Number thinned out Average length (cm) Average weight (g) Total weight (kg)				
Harvesting date Total period of growth (days) Number harvested Average length (cm) Average weight (g) Total weight (kg)				

Total number recovered including those thinned out earlier Percentage of survival				
Average growth (weight): per day per ha per annum per ha per annum per ha for all species together				

For a proper assessment of the growth recorded it is necessary to correlate the same with the manure applied and the artificial feed given during the period. The nutrient value of manures and feed have to be considered for this purpose. The performance of individual species has to be critically examined in order to decide about necessary variations in density or combination.

The stock of fish in the pond, at all stages is subject to hazards of predation, parasites and disease. Parasites and diseases are of diverse types and occur in all types of habitats and conditions. Detailed records of the environments, the state of the affected fish individually, as a species and as a constituent of the community, the symptoms of the disease or attack, the stages attacked or affected and measures taken have to be carefully maintained in order to attempt some sort of standardization in this aspect of work.

Date____________________ Pond____________________ Locality________________________

Fish population in the pond.

(Tabular statement of species with size)

Other organisms present.

(Tabular Statement)

Species of fish affected____

____

(Tabular statement of affected species, size, number affected, etc.) Nature of disease (Symptons to be described in detail)

____

____

____

____

Disease-causing agent (Description)____

____

____

Mortality of fish, if any____

Water conditions in the pond.

(Tabular Statement)

Curative/preventive measures adopted____

Results of treatment____

5 CONCLUSION

The chief principle and aim of fish culture the world over is increased production of selected species of fish through judicious manipulation of the environment. While the response to various treatments and techniques in different habitats in different countries, by different species may be different, the methods employed and the results achieved in different localities should be comparable so as to avoid duplication and waste of effort and funds. Standardization of techniques is necessary not only for the better utilization of knowledge but also for hastening progress in our knowledge of this important field of activity. Perhaps the fundamental step in such an attempt is ensuring some uniformity in the manner in which basic data on various aspects of fish culture are recorded and maintained. This working paper has been prepared with this objective in view.

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TESTING PLANT MATERIALS FOR DETECTION OF OXYGEN-DEFICIENT WATER IN PONDS

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Abstract

An easy method of determining the extent of oxygen deficiency in ponds, using the staining qualities of plant materials, is described. Woods, barks, leaves and fruits of many kinds of plants stain dark in pond water that contains less than approximately 0.2 ppm dissolved oxygen, whereas they do not stain in well-aerated water. Stain results from the reaction of ferrous iron in the water with tannic acid in plant materials. Suitable woods stained within 10 to 15 minutes in laboratory tests, and within 30 to 45 minutes in pond tests. Both fresh and dried materials stained in oxygen-deficient pond water.

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ESSAIS DE MATIERES VEGETALES SERVANT A DECELER L'INSUFFISANCE EN OXYGENE DE L'EAU DES ETANGS

Résumé

Description d'une méthode facile permettant de déterminer, grâce à la faculté de coloration de certains végétaux, le degré d'insuffisance en oxygène des étangs. Le bois, l'écorce les feuilles et les fruits de nombreuses espèces végetales prennent une teinte sombre lorsqu'ils sont immergés dans une eau contenant moins d'environ 0,2 ppm d'oxygène dissous, alors qu'ils ne changent pas de couleur dans une eau bien aérée. Le phénomène de coloration est dû à une réaction que se produit lorsque les composés ferreux de l'eau sont mis en présence de l'acide tannique contenu dans les matières végétales. Des morceaux de bois appropriés se sont colorés au bout de 10 à 15 minutes lors d'essais en laboratoire, et au bout de 30 à 45 minutes lors d'essais en étang. La coloration s'obtient aussi bien avec des matériaux frais qu'avec des matériaux secs dans les eaux déficitaires en oxygène.

ENSAYO DE MATERIALES VEGETALES PARA LA DETECCION DE LA DEFICIENCIA DE OXIGENO EN EL AGUA DE LOS ESTANQUES

Extracto

Se describe un método fácil para determinar el grado de desoxigenación de los estanques, utilizando las propiedades colorantes de los materiales vegetales. Las maderas cortezas, hojas y frutas de muchas clases de plantas dan un color oscuro al agua de los estanques que contiene menos de 0,2 pp, aproximadamente de oxígeno disuelto, en tanto que no coloran las aguas bien aireadas. La coloración procede de la reacción de los compuestos ferrosos que hay en el agua con el ácido tánico existente en los materiales vegetales. Algunas maderas adecuadas dieron color al cabo de 10 a 15 minutos en los ensayos de laboratorio y de 30 a 45 minutos en los ensayos en estanques. El agua con suficiente oxígeno fué colorada tanto por materiales frescos como secos.

1 INTRODUCTION

Many fish culturists have experienced kills of fish as a result of oxygen-deficiency in ponds. Knowledge of oxygen-deficiency beforehand could have enabled pond owners to save fish populations in numerous instances. While fisheries biologists can detect oxygen-depletion in ponds, most pond owners have neither the training nor the equipment to carry out the necessary tests.

Dendy (1965) reported that anaerobic water stained certain woods, but well-aerated water did not. This work provided pond owners a method for determining depths to which dissolved oxygen is distributed in ponds. Approximately 50 kinds of North American woods were tested for staining in anaerobic waters. The results varied from excellent to unsatisfactory. Desirable woods stained within 30 to 45 minutes.

The chemical basis of staining is the reaction of tannic acid in the wood with ferrous iron in waters that are anaerobic or have no more than approximately 0.2 ppm of oxygen. This soluble form of iron changes to insoluble ferric iron in well-aerated water, which does not react with tannic acid.

This paper describes the testing of plant materials to determine their suitability in detecting oxygen-deficient water in ponds.

2 CHEMISTRY OF PONDS

Stratification of water in ponds is common, especially during hot weather when there is little or no wind. When water that is oxygenated from the air and from photosynthesis does not circulate throughout the pond, the deeper layers develop a shortage of oxygen. In fertile waters containing blooms of phytoplankton, the zone of well-oxygenated water often becomes relatively shallow. During nights the supply of oxygen may be reduced to such low concentrations that fish have too little oxygen for respiration. Fish culturists can often save their fish by pumping surface water into the air and letting it fall back into the pond. This drives additional air into the pond and helps circulate the water. If pumps are not available, outboard motors or various manual methods may be used to stir the water and cause circulation in small ponds.

Whatever the method of stirring may be, there is always the question of when it is needed. If the pond owner waits until fish are in distress, or begin to die, losses may be considerable before the conditions can be corrected. The purpose of this paper is to describe how pond owners may avoid fish kills by determining the extent of anaerobic water in ponds before conditions become dangerous to fish.

3 MATERIALS

3.1 Tannic acid

Many plants throughout the world contain tannic acid. It may be found in such parts of the plants as barks, leaves, fruits, and woods. Howes (1953) lists many plants of various regions that have tannic acid in quantities sufficient to be of commercial value in the leather industry. The amounts of tannic acid in some plants may be too small for use in the leather industry, but are highly satisfactory for staining reaction in ponds. For this use the plant material should be light in colour and possess enough tannic acid to produce a conspicuous stain.

3.2 Water with ferrous iron dissolved in it

Most ponds have sufficient iron in them for testing. However, the pond must be deep and fertile enough to develop anaerobic or almost anaerobic conditions to have iron in soluble ferrous form.

4 TESTING PLANT MATERIALS

4.1 Laboratory tests

To test which local plant materials can be used, list plants and prepare thin shavings of wood, bark, small twigs, petioles of leaves, and veins of leaves. Dried materials are desirable and can be stored for subsequent use. Since fresh material frequently stains well it too should be tested. Crushed fresh leaves of some plants stain where the tissues have been broken. Dried tea leaves contain tannic acid, but may be too dark to show stain distinctly. Fresh leaves should be tried. The thinness is important. The feather-edge of a wood shaving shows staining more readily than do thicker parts. If very thin shavings are not available, the thin fibres of broken and of small pieces will suffice.

Prepare a fresh solution of ferrous sulphate (0.5 to 1.0 g per l of water). This solution will be usable for a few hours.

Use pairs of glass or porcelain containers with well-aerated water in one and ferrous sulphate solution in the other. Approximately 25 ml of water or solution will be ample. Immerse one piece of plant material in water and a similar piece in ferrous sulphate solution. Staining may be quite noticeable within one minute if the material is highly suitable but 10 to 15 minutes of exposure should be allowed before terminating the test. Slight stirring of the liquid will hasten the staining.

After a period of exposure, remove the material from water to determine the wet but unstained colour. Then, remove the material from the ferrous sulphate solution to determine the presence of stain. Useful material will show an obvious darkening. If the woody substance is light coloured and contains a sufficient amount of tannic acid, the stain will be a dark purplish blue.

The tannic acid from some plant material tends to dissolve into solution, causing it to become discoloured, especially fresh material that contains a high concentration of tannic acid.

4.2 Pond tests

After laboratory tests have been made, select the material that stained well, and a pond that is relatively deep and fertile. Tie a weight on one end of a string, and attach small pieces of the material at intervals of approximately 0.1 metre. Lower the weight into the water until it reaches the bottom, and then tie the string to a float or other support to ensure that the string is held in a vertical position. Allow 30 to 45 minutes for staining to take place. Remove the string and compare the colours of the plant materials. A dark purplish blue stain indicates a lack of oxygen in the water to which the material has been exposed. Faint darkening results when approximately 0.2 ppm of oxygen is present. Differences in colour can be distinguished easily by comparing an unstained piece of plant that was exposed in the aerated water near the surface with a piece that was exposed in anaerobic deep water.

4.3 Pond tests without previous laboratory tests

Tie a weight to the end of a string. At approximately 0.1 m above the weight attach several labelled pieces of different plant materials. At a position on the string that will be approximately 0.1 m beneath the surface attach similar labelled pieces. Expose the samples for 30 to 45 minutes and then remove from the water to compare staining. If staining occurs on certain woods they are suitable for further tests and the pond is suitable for further tests at 0.1 m intervals. If no staining occurs other plant materials should be tested, or the water of that pond contains dissolved oxygen at all depths, and another pond should be used for the tests.

5 DISCUSSION

Preliminary tests should be made by fisheries biologists who can check their results by use of standard chemical analyses. They will find that water with enough oxygen to support fish does not stain the plant materials. However, it must be remembered that the absence of stain does not indicate an abundance of oxygen. Even a concentration of 0.5 ppm of oxygen produces no stain.

When the change from dark stain to no stain occurs within approximately 0.2 m the water of the upper layers is usually well-aerated. When the change from dark stain to no stain extends through a layer 1 to 2 m thick, the layer immediately above probably contains relatively little oxygen. If water that stains the wood slightly is within 1 m of the surface this should be considered a danger signal, especially if half or more of the volume of water is at depths that produce stain.

6 RECOMMENDATIONS

Fisheries biologists should determine the suitability of locally available plant materials for use by pond owners. Then the use should be demonstrated to pond owners. Emphasis should be made on the inexpensiveness and simplicity of the technique.

Pond owners should keep a supply of desirable plant material. It is important that ponds be tested frequently during periods of hot weather and little wind.

Tests should be conducted at dawn, the period when oxygen is minimal. Remedial stirring must be started promptly if staining indicates the beginning of oxygen deficiency near the surface.

If a desirable kind of wood is available in lengths somewhat greater than the depth of the pond, a piece can be marked at 0.1 m intervals and be held in place by pushing one end into the bottom of the pond. After the period of exposure in water, the wood is examined for stain. A stained piece of wood can be reused after trimming one side. One piece of wood a few centimetres thick will be adequate for many tests.

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VI/E-2

AN OPTICAL METHOD FOR THE ESTIMATION OF THE STANDING CROP OF PLANKTON IN PONDS AND LAKES

by

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Abstract

Initial nephlometric measurements of plankton density in individual samples were compared with dry weights of plankton concentrated from samples by centrifuging to determine if a direct relationship existed between the two methods of measuring the standing crop of plankton. A definite linear relationship was found to exist between dry weights and initial nephlos measurements. It was concluded that the nephlometric technique may be used to reliably measure the standing crop of plankton in fresh-water impoundments.

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VI/E-2

UNE METHODE OPTIQUE POUR L'ESTIMATION DE LA BIOMASSE DE PLANCTON DANS LES ETANGS ET LES LACS

Résumé

L'auteur a comparé des mesures initiales méphélométriques de densité du plancton dans les échantillons individuels avec le poids sec d'échantillons de plancton concentrés par centrifugation afin de déterminer s'il y avait une corrélation directe entre les deux méthodes utilisées pour mesurer la biomasse de plancton.

L'existence d'une relation linéaire nettement définie entre le poids sec et les mesures initiales de turbidité a été établie.

L'auteur en conclut que la technique néphélométrique peut être utilisée pour mesurer avec précision la biomasse de plancton dans les étangs d'eau douce.

METODO OPTICO PARA LA ESTIMACION DE LA RIQUEZA POTENCIAL DE PLANCTON EXISTENTES EN ESTANQUES Y LAGOS

Extracto

Las medidas nefelométricas de la densidad del plancton obtenidas en muestras individuales fueron comparadas con el peso en seco del plancton concentrado procedente de las muestras mediante centrifugación, para determinar si existía una relación directa entre los dos métodos de medir los efectivos de plancton existentes. Se comprobó que existía una relación lineal entre el peso en seco y las medidas del enturbamiento. Se llegó a la conclusión de que la técnica nefelométrica puede ser utilizada para medir con garantía la riqueza potencial de plancton en las masas cerradas de agua dulce.

1 INTRODUCTION

In studying the productivity of an ecosystem such as that of a fresh-water pond or lake managed for maximum production of harvestable fish, it is essential that some measure be taken of the relative abundance of plankton, in order to evaluate the potentials of the system. A measurement of the standing crop of plankton will indirectly give an indication of the fertility of the total ecosystem.

1.1 Methods of evaluating plankton abundance

The usual method of evaluating plankton productivity involves a measurement of the amount of material produced per unit area or volume over a given period such as 24 hours or even a year. This is a measure of the primary productivity of the system and is the only true measure of the overall fertility. Methods for determining primary productivity are often difficult and time-consuming; consequently, the detailed primary productivity study is in many instances rejected in favour of some other method of estimating productivity.

To obtain an estimate of productivity of a pond ecosystem, a quantitative plankton study is often conducted. The classic methods involve a gravimetric determination or enumeration of the standing crop of plankton in the pond, i.e., a measure of the total abundance of organisms present at any one time.

The standard limnological procedures followed in gravimetric plankton studies are extremely time-consuming. From 24 to 48 hours are required to obtain dry weights on individual plankton samples. This extended procedure places strict limitations on number of samples that can be analyzed during a sampling period and thus severely affects the usefulness of the technique.

Turning to other methods for determination of plankton abundance, certain optical techniques appear promising. Optical methods utilizing the Tyndall effect in measurement of turbidity of suspensions of bacterial or algal cell cultures are described by McFarland (1907), Preskett (1927), and Lund and Talling (1957). Diller and Kersten (1954) described a method for the determination of algae concentrations. Studying Chlorella cell suspensions, they obtained a linear relationship between turbidity readings and the dry weights of Chlorella.

Turbidimetric methods were adapted by Laevastu (1957) for the estimation, on a quantitative basis, of the standing crop of plankton in off-shore waters. Estimations were made in situ by passing water continuously through a beam of light in a chamber and measuring refracted or Tyndall light bounced off the plankton particles with a photocell. By calibrating the apparatus for average phytoplankton, Laevastu obtained a rough continuous measure of the amount of plankton in the surface layer.

This paper is a report of investigation of use of an optical turbidimetric method for estimation of the standing crop of plankton in small fresh-water impoundments. Experimental studies were conducted at the Fisheries Farm Pond unit of the Agricultural Experiment Station, Auburn University, Auburn, Alabama.

2 METHODS

Plankton samples were collected from a series of 144 plastic pools, each 0.0006 ha (1/685 acre), and from a series of earthen ponds each 0.1 ha (0.25 acre) in size. Collections were made during a five-month period from June to November, 1963. Samples were brought into the Fisheries Laboratory and maintained at a temperature of 75°C under approximately 600 foot candles of continuous light for a period of not longer than 36 hours before analysis.

The major dominant forms of phytoplankton present in each sample were identified to genera and a listing was made of the prominent algae in each sample. Two litre subsamples were removed from the sample collection jars and placed into a gravity-flow system for analysis. The gravity-flow apparatus consisted of a 2,000 ml volumetric flask held in support on a ring stand with a flow tube leading to the in-flow part of a Type SS-1 Servall Angle Centrifuge. The centrifuge was equipped with a "Szent-Gyorgyi and Blum" 8-tube continuous-flow system. The complete system is illustrated in Fig.1.

The speed of the centrifuge was governed by a variable voltage regulator. A top rotor speed of 15,000 R.P.M. was used with all samples. At this speed the relative centrifugal force developed was 31,890 x g.

The flow rate through the gravity flow system was governed by a flow-tip constructed with drawn glass tubing and ground to deliver one litre every six minutes. Each 2-litre subsample was run through the centrifuge three times in a continuous nonstop operation. Total centrifuge time for each sample was approximately 40 minutes.

Plankton accumulated in the centrifuge tubes was transferred into pre-weighed tubes and dried at 60°C for approximately 24 hours. Upon completion of drying, sample concentrates were placed in desiccators for a minimum period of 24 hours. The dry weights of recovered plankton were subsequently determined to the nearest 0.1 mg on an analytical balance.

A standing procedure was followed in the nephlometric analysis of the turbidity of all plankton samples. Each plankton collection jar was shaken or stirred thoroughly and a small volume was removed to fill a 10 x 105 mm cuvette tube. A Coleman Model 9, Nepho-Colorimeter was standardized at a nephlos value of 3 using filtered distilled water, samples were then taken by inserting the sample cuvette into the immersion well of the instrument and recording the lowest nephlos value in a one minute period as read on the galvanometer deflection scale.

3 RESULTS

The results, Fig. 2, are based on the values obtained from analysis of 48 plankton samples in which the phytoplankton composed the major portion of the living plankton. Since the phytoplankton was dominant in all samples an attempt was made to identify the major algal forms to genera. No identification was attempted with the zooplankton forms.

The Chlorophyta were dominant in all samples with genera of the families Desmidaceae, Oocystaceae, and Scenedesmaceae occurring very abundantly during the sampling period. Among the diatoms, several genera of the families Fragilariaceae and Naviculaceae were represented extensively. The division Cyanophyta was represented by the filamentous genera Anabaena, Anabaenopsis, Lyngbya, and Oscillatoria. Microcystis, a colonial blue-green alga, was exceedingly abundant in the ponds at Auburn during the summer and early fall months.

To determine the relationship between optical and gravimetric measures of plankton abundance in the ponds, the dry weights of plankton (mg/ℓ) collected by the Servall centrifuge were plotted against the initial nephlos measurements (Fig. 2).

The general grouping of the points on the plot indicated the existence of a direct relationship among the observed nephlos values and the plankton weights. To determine if a linear relationship existed, standard regression analysis was carried out according to procedures outlined by Steel and Torrie (1960).

From the collected data, the calculated regression equation was

$\hat{Y}=1.83 + 0.16x$, when Y = mg/ℓ dry plankton, and X = nephlos reading

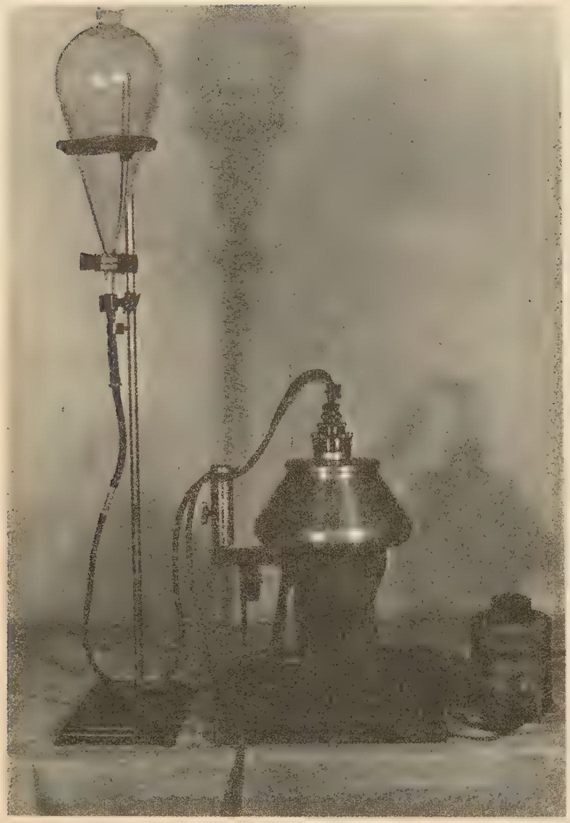

Fig.1 Servall centrifuge and gravity flow system

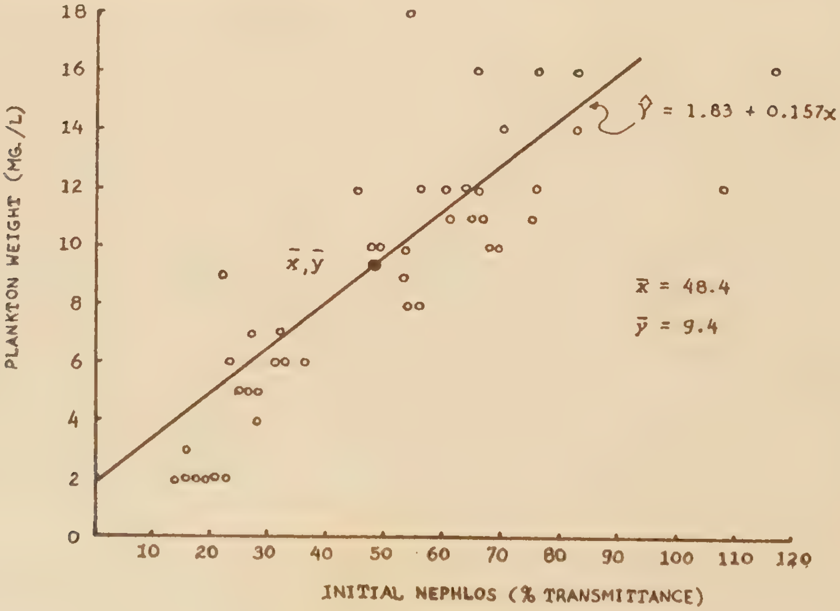

Fig. 2 Relationships between nephlos readings and mg/l dry weights of plankton in pond water

This regression line is shown in Fig. 2. A "t" test demonstrated the significance of "b" at the one percent confidence level. It was concluded that a definite linear relationship existed between the two measures of plankton density.

4 DISCUSSION

From a visual comparison of points in Fig. 2, and results of regression analysis, it is evident that use of nephlos values as indicators of plankton abundance is as valid as use of dry weights obtained by centrifuging. Since it required only one to two minutes to obtain a nephlos reading, as compared with a minimum of 24 to 48 hours to obtain the dry weight of a plankton sample by standard methods, and since the nephlometric technique appears to be equally reliable, the use of the nephlometric method would be considerably more economical than the gravimetric.

From results of this initial investigation, it appears that evaluation of plankton abundance, or overall standing crop, by optical nephlometric analysis is an accurate and useful technique. There are, however, some limitations of application of this type of analysis.

The nephlometer measures the concentration of all suspended particles in a sample. The nephlometric method, therefore, is applicable only in those situations where the major portion of the suspended material is organic in nature. A measurement taken in waters receiving a considerable inflow of inorganic silt and detritus, that is subsequently held in suspension, would not give a true measure of the total plankton abundance. In fresh-water ponds which are managed for increased yield of sport fish, regular applications of inorganic fertilizers causes a precipitation of a large portion of the suspended colloidal silt particles in the water; it also leads to a subsequent build-up of plankton organisms.

The suspended material in most pond waters consists of living plankton, largely phytoplankton, plus a considerable amount of dead organic material, detritus. This combination of living and dead organic material is known as seston. An initial nephlometric measurement of the concentration of suspended particles in a sample is in actuality a measure of the total seston in the water.

Pennak (1949) in a study of some Colorado reservoir lakes estimated that organic detritus accounted for 40-90 percent of the total bulk of the seston. He stated that the measure of mean annual seston or of total seston is a valuable and reliable index of comparative plankton production in terms of standing crop since seston is less variable than either zooplankton or phytoplankton

According to Pennak (1946), the major portion of the food of the zooplankton in fresh-water lakes is detritus rather than living algae. This conclusion is supported by the fact that there is seldom, if any, numerical relationship between pulses of zooplankton and phytoplankton. If this hypothesis is accepted, a measurement, by nephlometry, of the detritus included in the seston would give, in general, an indication or rating of the existing biological potential of the ecosystem of a pond or lake.

The exact manner by which organic matter influences productivity is not known. The generally accepted concept of the food chain assumes that the zooplankton feeds on the phytoplankton with the higher organisms feeding in turn on the zooplankton. It is possible, however, that the higher organisims may feed directly on the suspended organic particles in the water rather than depending on the zooplankton. It is reported that certain fish larvae will take suspended particles of 20 to 30 microns in diameter (Hanaoka, 1957). The organic detritus may, therefore, actually form the basic link in the food chain.

Where plankton and detritus concentrations are very dense it becomes necessary to dilute the sample to obtain a reading on the galvanometer scale, thus introducing a source of error in the method. In this study dilution ratios of 2:1 were frequently used with a subsequent correction of the nephlos reading by a factor of three. Dilutions beyond this ratio may lead to inaccurate readings; however, this was not tested. The assumed accuracy of the optical nephlometric technique was between the nephlos values of 0 to 120.

The nephlometer cannot be used to measure the density of plankton concentrations in which certain forms of blue-green algae are predominant, in particular, the genera *Coelosphaerium*, *Microcystis*, and *Anabaena*, which often form intense "blooms" during the summer and fall months in the southern United States. These contain pseudovacuoles or gas vacuoles in the cells which give an added light-scattering effect, indicating concentrations much greater than that actually present in the sample, so nephlometer measurements of plankton concentrations in waters containing these forms will be inaccurate. Unless some method is devised to disrupt the gas vacuoles in the cells, the nephlometric technique cannot be used in those instances where these algae are dominant in the phytoplankton.

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THE RELATIVE EFFICIENCY OF EXPERIMENTS CONDUCTED IN UNDIVIDED PONDS AND IN PONDS DIVIDED BY NETS [1]

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Abstract

The random variation between the production of the two halves of a single pond divided by nets, was compared with the random variation between adjacent ponds. The experiments were conducted with carp (Cyprinus carpio), and were repeated during three seasons. It was shown that the variance of the differences between adjacent ponds is several times higher than that of the differences between the two halves of a pond divided by a net.

Since the relative efficiency of experimental designs is an inverse function of their 'error' variances, it was concluded that stock testing is much more efficient in divided ponds, than in separate ponds.

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VI/E-3

EFFICACITE RELATIVE DES EXPERIENCES MENEES DANS DES ETANGS NON COMPARTIMENTES ET DANS DES ETANGS COMPARTIMENTES PAR DES FILETS [1]

Résumé

La variation aléatoire entre la production de deux moitiés d'un étang compartimenté par des filets a été comparée à la variation aléatoire entre étangs adjacents. Les expériences, pour lesquelles on a utilisé des carpes (Cyprinus carpio), ont été répétées pendant trois saisons. Il a été prouvé que la variance des différences entre étangs adjacent est plusieurs fois plus élevée que celle des différences entre les deux moitiés d'un étang compartimenté par un filet.

Etant donné que l'efficacité relative des dispositifs expérimentaux est en fonction inverse des variance de l'erreur, les auteurs ont conclu que les essais sont nettement plus efficaces dans des étangs compartimentés que dans des étangs séparés.

LA EFICACIA RELATIVA DE LOS EXPERIMENTOS REALIZADOS EN ESTANQUES NO DIVIDIDOS Y EN ESTANQUES DIVIDIDOS POR MEDIO DE REDES [2]

Extracto

La variación aleatoria entre la producción de las dos mitades de un solo estanque dividido por medio de redes, se comparó con la variación aleatoria entre estanques adyacentes. Estos experimentos se realizaron con carpas (Cyprinus carpio), ye se repitieron durante tres temporades. Se comprobó que la variancia de las diferencias entre estanques adyacentes es varias veces mayor que la de las diferencias entre las dos mitades de un estanque dividido por medio de una red.

Como la eficacia relativa de los diseños experimentales es una función inversa de sus variancias por "errores", se llegó a la conclusión que la comprobación de la población es mucho más eficaz en los estanques divididos que en los estanques separados.

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[2] El trabajo presentado en este artículo pudo hacerse, en parte, gracias a las donaciones de la Oficina de Pesca Comercial, Servicio de Pesca y Vida Silvestre, Departamento del Interior, Gobierno de los Estados Unidos, y de la Associación de Piscicultura de Israel.

1 INTRODUCTION

In fish culture research it is often necessary to compare the yield capacity of different stocks of fish. A common way of doing this, is to plant each stock in several ponds, and compare their average yields. However, this method is under the major disadvantage, that random (unexplained) variation, even among adjacent ponds, is very high; considerably higher, for example, than the variation that is usually found among adjacent plots of field crops. Thus it is frequently found, that a prohibitively large number of ponds is required for the detection of significant differences among the tested stocks.

A common procedure for overcoming the above difficulty is to test several stocks in the same 'communal' pond. This design separates the 'between-stocks' variation from the 'between-ponds' one. Unfortunately, it introduces another complication, namely, interactions between the tested stocks (Wohlfarth, Moav and Lahman, 1961; 1965). When, for example, the variable of interest is yield capacity, while the measured variable is relati growth rate, it is necessary to know the correlation between the two for the specific stocks under test, in order to interpret properly the results of the comparative trials. This information is rarely available, and there is probably no a-priori assumption applicable to this relationship.

We have experimented with a third method of testing, namely, dividing a pond by means of wire-nets, and planting the stocks under test separately in the different parts of the same pond. The results of these experiments, which are described in the present article, show that this method is several times more efficient than planting the stocks under test in different ponds.

2 A MEASURE OF THE RELATIVE EFFICIENCY

The relative efficiency, to be designated Ef, of ponds divided by net, can be defined as the number of undivided ponds (N_{bp}), that are required for a statistical test of a given level of significance, divided by the number of divided ponds (N_{wp}) needed for a statistical test of equal significance and power.

$$Ef = \frac{N_{bp}}{N_{wp}} \qquad (1)$$

It can readily be shown that (1) can be expressed as (see appendix):

$$Ef \quad \frac{\sigma^2_{bp}}{I\,\sigma^2_{wp}} \qquad (2)$$

when σ^2_{bp} is the 'error' variance of differences between ponds, σ^2_{wp} is the error variance of differences between parts of the same pond, and I is the number of tested stocks.

For the simple case, when only two stocks are tested in ponds that are divided into two equal halves, the Student's t variable can be used for the test of significance, and Ef can be expressed as:

$$Ef = \frac{\sigma^2_{bp}}{\sigma^2_{d}} \qquad (3)$$

σ^2_d is defined as the 'error' variance of the difference between the two halves of the same pond, and it is equal to 2 x σ^2_{wp}.

Formulae 2 and 3 show that in order to estimate the relative efficiency of divided ponds we only need estimates of the 'between-ponds', and 'within-ponds-between partitions' variances.

3 EXPERIMENTAL RESULTS

The efficiency of dividing small ponds into two equal halves, for the testing of two different genetic stocks, was estimated at Dor, with carp (Cyprinus carpio) fingerling in ponds of 400 m^2. The tests were repeated during three seasons. A number of ponds were divided length-wise (North-South) into two equal halves, each half of the same pond was planted with a different stock of carp. The undivided ponds were planted with single stocks. The 'between-halves' variances σ^2_{wp} and the 'between-ponds' variances σ^2_{bp} were computed and the results are presented in Table I. The table shows that the divided ponds were several times more efficient than the undivided ponds. It should be noted that in the summer the experiments were conducted with small fingerlings at a relatively high density of stocking, while in the autumn larger fish were used, at a lower density of stocking. Due to the shorter duration of the autumn experiment the yields and consequently the variances were relatively smaller.

Table I

Relative efficiency of ponds divided by nets
compared with undivided ponds

Experiment	Average wt. of fish		Density (fish per dunam)	Divided ponds		Undivided ponds		Relative efficiency 1/
	Initial	Final		No. of ponds	$2\sigma^2_{wp}$ 1/	No.	σ^2_{bp} 1/	
Summer 63	41	675	185	9	2.28	18	37.6	16.5
Summer 64	25	620	235	8	2.19	20	12.3	5.6
Autumn 64	606	962	100	7	0.42	15	1.44	3.5

1/ see text

4 DISCUSSION AND CONCLUSIONS

It should be pointed out that under certain conditions, interactions between the parts of a divided pond may occur. For example, when the parts of the same pond are stocked with fish of the same growth capacity but in different densities, the denser side will produce smaller fish, but higher yields. When there is a difference in growth capacity between the fish stocked in the two sides, and the number of fish is equal, the group with the higher growth capacity will benefit from the smaller volume of fish in the second half. In general, when the bio-mass (corrected for size of fish) in the two sides of the pond is unequal, the size with the higher bio-mass will benefit from the lower bio-mass of the other half.

The possible existence of interactions between groups of fish separated by nets means that care should be taken when these results are interpreted in terms of yields of undivided ponds. For tests of different stocks of fish, the best procedure is to start the experiment with fish of equal initial weights and at equal densities.

When the object of the experiment is to test different treatments, such as feeding or fertilizing formulae, rather than different stocks of fish, the problem of interactions between the two sides of the nets may be considerably more serious, and the results obtained may be significantly different from those obtained with separate ponds.

The observation that the variation between adjacent ponds of equal size and apparently equal conditions is several times larger than the variation between the two halves of a pond divided by nets, may be interpreted to mean that random variation in the organic development within the water of a pond is a major source of variation of yield of adjacent and otherwise similar ponds.

Many problems of fish culture, require a prohibitively large number of ponds for their solution. If the present findings can be generalized, then a judicial use of ponds divided by nets may contribute significantly to the solution of some of these problems.

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6 APPENDIX

When I stocks are tested, each at J ponds of equal size, then the total number of ponds is $N_{bp} = IJ$. A statistic that tests the hypothesis that there are no differences among the stocks is F, whose expected value is

$$\frac{\sigma^2_{bp} + J\sigma}{\sigma^2_{bp}} \tag{1A}$$

σ^2_{bp} designated the 'error' variance of differences between ponds, and σ designates the following function of the deviations σ_i (i = 1,2.....I) of the stocks, from their grand mean

$$\sigma = \frac{1}{I-1} \sum_{i=1}^{I} \sigma_i^2$$

Since $N_{bp} = IJ$, formula 1A can be written as,

$$\frac{\sigma^2_{bp} + \frac{N_{bp}}{I}\sigma}{\sigma^2_{bp}} \tag{2A}$$

When the same I stocks are tested in N_{wp} ponds, each divided by nets into I equal parts, the expected value of the appropriate F statistics is:

$$\frac{\sigma^2_{wp} + \frac{N_{wp}}{I^2}\sigma}{\sigma^2_{wp}} \tag{3A}$$

The division of N_{wp} by I^2 rather than by I, is due to the fact that σ_i is defined as a deviation of the yield of the whole pond which is I times higher than the yield of a part of a divided pond.

For tests of equal performance by the above two methods formulae 1A and 2A should be equal. This relationship shows that the relative efficiency Ef, can be expressed as a ratio of variances, (equation 2 of text).

$$Ef = \frac{N_{bp}}{N_{wp}} = \frac{\sigma^2_{bp}}{I\sigma^2_{wp}} \qquad (4A)$$

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